Revision R02 Version 04, 7 November 2023

Manuscript Title: *Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and surface radiation impact* **by Ricaud et al.**

RESPONSES TO THE EDITOR

Dear Dr. Ricaud,

Thank you for your extensive revisions to the paper. I invited the original reviewers, as well as to an additional expert for their review of the paper. They are all in agreement that the paper is potentially highly valuable to the community, but that it is crucial in this case to use a radiative transfer model to validate your work. I strongly encourage you to address these concerns. To give you ample to time, I will reconsider after major revisions.

→ Dear editor, we have modified the section relative to the estimation of the cloud-free irradiance. It took some time to converge toward the most appropriate solution. We believe the revised version now meets the reviewers' concerns.

In the Acknowledgements, we have updated the number of reviewers (from two to three):

> *We would like to thank the three anonymous reviewers for their beneficial comments.*

Also note, to be consistent with the reviewers' comments, we have modified the title from:

> *Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and surface radiation impact*

to

> *Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and radiative forcing*

Report #1
Reviewer2

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

I thank the authors for updating their manuscript and their extensive response. However, I must admit that I am even more confused than before. I still think that simply ignoring the diurnal cycle when estimating reference SR by a mean value cannot be correct. I understand that ERA5 cannot handle sastrugi effects, but what is going on with ERA5 so that LW down is wrong by 30 W/m2 for a simple clear sky case? Or is that a measurement problem? Maybe I am also overlooking something here. This looks to me like this paper needs a reviewer who is an absolute expert in SW/LW radiation, my expertise is more in the microwave range. Therefore, I do not feel qualified to give a recommendation here (even though the system forces me to select a box).

→ Thank you for your valuable comments. We have removed the study based on ERA5 and CERES data. This is explained in detail in the responses of the reviewer3's comments.

One more minor comment: please use T instead of Θ for temperature, the latter is usually used for potential temperature, so the use of Θ is very confusing.

→ Done, "θ" has been changed into "T".

Anonymous Referee #3

Referee comment on "Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and surface radiation impact" by Ricaud et al.

→ 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 study investigates the relation between temperature and liquid water path in the presence of supercooled liquid water clouds, and analyzed the cloud radiative effect in terms of net surface radiation.

In general, the authors have attempted to thoroughly revise their manuscript according to the reviewers' comments. The relationship between temperature and LWP is well described. However, I have still some concerns regarding the methodology used to estimate the cloud radiative effect. Overall, I cannot recommend publication without a major revision.

→ Thank you for your valuable comments. We explained below the new methodology employed.

Also note, to be consistent with your comments, we have modified the title from:

Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and surface radiation impact

to

Supercooled liquid water clouds observed over Dome C, Antarctica: temperature sensitivity and radiative forcing

Major Comments

1. In the revised version, the authors included ERA5 and CERES data to evaluate the surface radiation in cloudless conditions. I don't think this significantly supports the study for several reasons. First, a potential effect of surface roughness (sastrugi) on surface albedo could be directly estimated from the pyranometer measurements. Second, it is not clear to me, for what reason ERA5 and CERES data were introduced here. It is known, that these data sets are not very reliable in representing the surface albedo, as also shown by the authors. Both data sets were fudged to the measurements by using the measured surface albedo for scaling the upward irradiance. What is to be done with the fitted results? How does it help to estimate the radiative effect of clouds based on the ERA5/CERES data, since they are still based on the near-time measured albedo? How do they prove the stability of conditions?

→ As suggested by the reviewer, we have definitely suppressed the use of ERA5 and CERES from the analysis and worked on the methodology proposed by the reviewer (see our response to the next comment).

2. A more feasible approach was already suggested by the previous reviewers. I strongly encourage the authors to use radiative transfer modeling to estimate the cloudless reference

surface radiation. Since the surface albedo are available directly from the measurements in cloudless conditions, even the diurnal pattern can be considered. Note, that snow/white ice albedo is also dependent on the solar zenith angle (e.g., Gardner and Sharp, 2010 - https://doi.org/10.1029/2009JF001444). Atmospheric profiles of temperature and humidity should be taken from radio soundings, as they provide a reliable description of the atmospheric state on the considered cloudy day. The use of longwave radiation measurements on cloudless days is not advisable because they are not representative of cloudy days. Temperature and humidity profiles have a strong effect on the longwave radiation.

→ We have taken some time to consider using radiative transfer models to validate our work. We have used the RRTM code (Mlawer et al., 1997) and performed clear and clean sky computations. As an input, we have used the following data:

- Temperature and specific humidity profiles from the radiosondes launched every day at 12:00 UTC from the Concordia station and assumed to be constant along each day,
- ERA5 ozone profiles,
- Yearly-mean greenhouse gas concentration from NOAA, assuming these gases are well-mixed,
- Surface temperature diagnosed from the BSRN surface longwave fluxes crudely assuming a surface emissivity of 0.99,
- Surface albedo diagnosed from the BSRN surface shortwave fluxes,
- Solar zenith angle based on the calculation performed within the ARPEGE atmospheric model used for operational weather forecasting at Météo-France.

Mlawer, E.J., Taubman, S.J., Brown, P.D., Iacono, M.J. and Clough, S.A.: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave. Journal of Geophysical Research: Atmospheres, 102(D14), 16663-16682, https://doi.org/10.1029/97JD00237, 1997.

We have performed calculations on the 5 cloud-free 24-hour periods available (2018-12-02, 2018-12-19, 2021-12-03, 2021-12-17, 2021-12-26) and calculated the root-mean square error (RMSE). Although the RMSE scores of the difference between surface irradiances observed by the BSRN instruments and the calculations in cloud-free conditions were acceptable for upward and downward shortwave (SW) surface irradiances with values less than 10 W m^{-2}, and upward longwave (LW) surface irradiances with values less than 1 W m^{-2}, they were not acceptable for the downward longwave surface irradiances with values ranging from ~10 W m^{-2} in 2018 to ~30 W m^{-2} in 2021. Similar calculations were done using ERA5 reanalyses or ARPEGE analyses to prescribe the time-evolving profiles of temperature and specific humidity. These two sensitivity tests only marginally improved the results.

We thus concluded that performing radiative transfer calculation was not the appropriate solution for our objectives, at least given the data to which we have access. Going back to the literature, we have found a more relevant option, that has been applied to several other site measurements to diagnose cloud-free surface fluxes. This approach is discussed in the following.

Before explaining our methodology to estimate the cloud radiative forcing, we have to mention that, according to the minor comments of the reviewer, we have changed the spelling and terminology of the "surface irradiance" terms in eq (1) as:

$$F_{Net} = \left(F_{LW}^{Down} - F_{LW}^{Up}\right) + (F_{SW}^{Down} - F_{SW}^{Up}) \quad (1)$$

where F_{Net}, F_{LW}^{Down}, F_{LW}^{Up}, F_{SW}^{Down}, and F_{SW}^{Up} represent the net, longwave downward, longwave upward, shortwave downward and shortwave upward surface irradiances, respectively. And we now write the "cloud radiative forcing" as ΔF:

$$\Delta F = F - FCF \quad (2)$$

for each term of equation (1), with FCF being the irradiance in cloud-free conditions.

Since radiative transfer modeling was unsatisfactory, to compute cloud-free surface irradiance in the LW and SW ranges, we follow the work of Dupont et al. (2008) and Dutton et al. (2004), respectively. Namely, in Dutton et al. (2004), cloud-free downward shortwave surface irradiance (FCF_{SW}^{Down}) is parameterized as:

$$FCF_{SW}^{Down} = a\ \cos(z)^{b}\, c^{\left(\frac{1}{\cos(z)}\right)} \quad (3)$$

where z is the solar-zenith angle, and a, b, and c are coefficients optimized using well-identified cloud-free situations. In Dupont et al. (2008), cloud-free downward longwave surface irradiance (FCF_{LW}^{Down}) is parameterized as:

$$FCF_{LW}^{Down} = \varepsilon_a\ \sigma\, T_a^4 \quad (4)$$

where T_a is the screen-level air temperature in Kelvin (K), σ the Stephan-Boltzmann's constant and ε_a the apparent atmospheric emissivity. The latter is supposed to be a function of the integrated water vapor (IWV) following the equation:

$$\varepsilon_a\ = 1 - (1 + IWV)\exp(-(d + e \times IWV)^{f}) \quad (5)$$

where d, e and f are coefficients that need to be optimized using cloud-free situations. The cloud-free upward shortwave surface irradiance (FCF_{SW}^{Up}) is evaluated from FCF_{SW}^{Down} with the surface albedo ($A_{BSRN} = F_{SW}^{Up}(BSRN)/F_{SW}^{Down}(BSRN)$) calculated from observations:

$$FCF_{SW}^{Up} = A_{BSRN}\ \times FCF_{SW}^{Down} \quad (6)$$

where $F_{SW}^{Up}(BSRN)$ and $F_{SW}^{Down}(BSRN)$ are the upward and downward shortwave surface irradiances measured by the BSRN instruments, respectively. With this method, we are able to take into account the diurnal variability of the surface albedo which is dependent on the sun angles because of the sastrugi effect present at Concordia. Note that a computationally simple, theoretically based parameterization for the broadband albedo of snow and ice can accurately reproduce the theoretical broadband albedo under a wide range of snow, ice, and atmospheric conditions (Gardner and Sharp, 2010).

The cloud-free upward longwave radiation (FCF_{LW}^{Up}) is evaluated as:

$$FCF_{LW}^{Up}\ = \varepsilon_s\ \sigma\, T_s^4\ +\ (1 - \varepsilon_s)\, FCF_{LW}^{Down} \quad (7)$$

where T_s is the surface temperature (in K) and the surface emissivity ε_s is assumed constant and equal to 0.99.

Screen-level temperatures T_a are provided by the American automated weather station (AWS) situated at ~500 m from the Concordia base. T_s is diagnosed based on equation (7) by using the BRSN upward and downward longwave surface irradiances. IWV is provided by the HAMSTRAD measurements.

Cloud-free situations are detected based on visual inspection of the LIDAR (depolarization) measurements. Depolarization ratios greater than about 1% are attributed to the presence of cloud (cirrus, mixed-phase, SLW), diamond dust, fog, etc. Thus, within each 24-hour slot covering the Decembers 2018-2021, the 1-hour periods when the depolarization ratios are less than 1% are considered as cloud-free periods. Consequently, to evaluate the surface cloud-free irradiances over the month of December and the years 2018-2021, we need to have coincident observations from the 4 BSRN instruments, the LIDAR (depolarization), HAMSTRAD and the AWS.

Table R1 lists the periods in Decembers 2018-2021 when cloud-free conditions (based on the LIDAR depolarization data) are encountered. If we consider the observations availability of HAMSTRAD (IWV), depolarization LIDAR, AWS (T_a) and BRSN surface irradiances, Table R1 actually shows all the periods when the parametric coefficients and thus the cloud-free irradiances can be evaluated.

Table R1. Cloud-free periods in December 2018-2021 detected from the Lidar depolarization observations at Concordia. Time is in UTC. MM-NN means from MM (included) hour UTC to NN (excluded) hour UTC. "X" means no cloud-free period during that day. "ND" means no LIDAR data available. Greyish cases means that cloud-free irradiance calculations are impossible due to lack of some data (LIDAR, HAMSTRAD, BSRN or AWS).

Days	2018	2019	2020	2021
01	0-24	9-18	ND	9-16
02	0-21	13-17	ND	7-8
03	0-24	6-16	ND	6-24
04	X	11-16	ND	0-24
05	X	6-16	3-16	12-19
06	3-6	0-13	9-13	2-12
07	1-16	X	X	0-24
08	3-15	X	1-2	0-10
09	2-16	X	4-14	10-17
10	0-3	X	X	ND
11	X	4-17	0-1	ND
12	X	X	20-22	ND
13	11-13	10-14	0-12	X
14	22-24	17-18	X	5-12 & 17-20
15	4-8	22-23	X	3-6
16	15-18	X	6-8	11-24
17	18-19	ND	X	0-24
18	1-17	ND	16-17	0-3
19	0-24	ND	7-9 & 11-13	20-23
20	0-12	ND	20-22	16-19

21	X	ND	20-21	X
22	9-16	ND	ND	12-15
23	1-4	ND	14-20	X
24	X	ND	11-14	0-6
25	X	ND	9-15	20-24
26	12-18	ND	0-16 & 18-22	0-24
27	10-11	ND	0-2	0-4
28	0-6	ND	0-17	10-14
29	X	ND	0-18	X
30	X	ND	7-24	X
31	10-12	ND	0-18	X

Dutton, E.G., Farhadi, A., Stone, R.S., Long, C.N. and Nelson, D.W.: Long-term variations in the occurrence and effective solar transmission of clouds as determined from surface-based total irradiance observations. Journal of Geophysical Research: Atmospheres, 109(D3), https://doi.org/10.1029/2003JD003568, 2004.
Dupont, J.C., Haeffelin, M., Drobinski, P. and Besnard, T.: Parametric model to estimate clear-sky longwave irradiance at the surface on the basis of vertical distribution of humidity and temperature. Journal of Geophysical Research: Atmospheres, 113(D7), https://doi.org/10.1029/2007JD009046, 2008.
Gardner, A.S. and Sharp, M.J.: A review of snow and ice albedo and the development of a new physically based broadband albedo parameterization. *Journal of Geophysical Research: Earth Surface*, *115*(F1), 2010.

Once cloud-free situations are identified, the parametric coefficients *a*-*f* are estimated minimizing a least-square cost function using the trust region reflective method (e.g., Branch et al., 1999). In practice, the 'curve_fit' function of the Scipy optimize module is used (Version 1.10.0). To assess the robustness of the estimated coefficient values, a K-fold cross-validation is performed. The learning dataset is split into 10 subsamples of equal size. 9 of them are selected to optimize the coefficient and the validation is conducted on the remaining subsample. The exercise is performed 10 times. The results are summarized below. Note that following Dupont et al. (2008), *f* is assumed to be equal to 1, and therefore not optimized.

For downward shortwave surface irradiance, the K-fold cross-validation provides the following K-fold average value (K-fold minimum and maximum are indicated within brackets):

$$a = 1360.7\ [1360.5, 1360.8]\ \mathrm{W\ m^{-2}}$$
$$b = 0.990\ [0.989, 0.991]$$
$$c = 0.964\ [0.964, 0.965]$$
$$\mathrm{bias} = -0.002\ [-0.317, 0.251]\ \mathrm{W\ m^{-2}}$$
$$\mathrm{RMSE} = 14.9\ [10.8, 16.5]\ \mathrm{W\ m^{-2}}$$

Similarly, for downward longwave surface irradiance, the K-fold cross-validation provides the following results:

$$d = 0.723\ [0.722, 0.724]$$
$$e = 3.58\ [3.57, 3.59]\ \mathrm{kg^{-1}\ m^{2}}$$
$$f = 1.0$$
$$\mathrm{bias} = 0.34\ [-0.005, 0.87]\ \mathrm{W\ m^{-2}}$$
$$\mathrm{RMSE} = 9.26\ [8.92, 9.58]\ \mathrm{W\ m^{-2}}$$

These coefficient values are used to compute cloud-free surface irradiances at a 1-min time resolution.

M. A. Branch, T. F. Coleman, and Y. Li, "A Subspace, Interior, and Conjugate Gradient Method for Large-Scale Bound-Constrained Minimization Problems," SIAM Journal on Scientific Computing, Vol. 21, Number 1, pp 1-23, 1999.

Based on these cloud-free calculations, we can now estimate the impact of the SLW clouds on the different components of the cloud radiative forcing. As an example, Figures R1 and R2 show the cloud radiative forcing ΔF on 9 December 2019 and 27 December 2021, respectively.

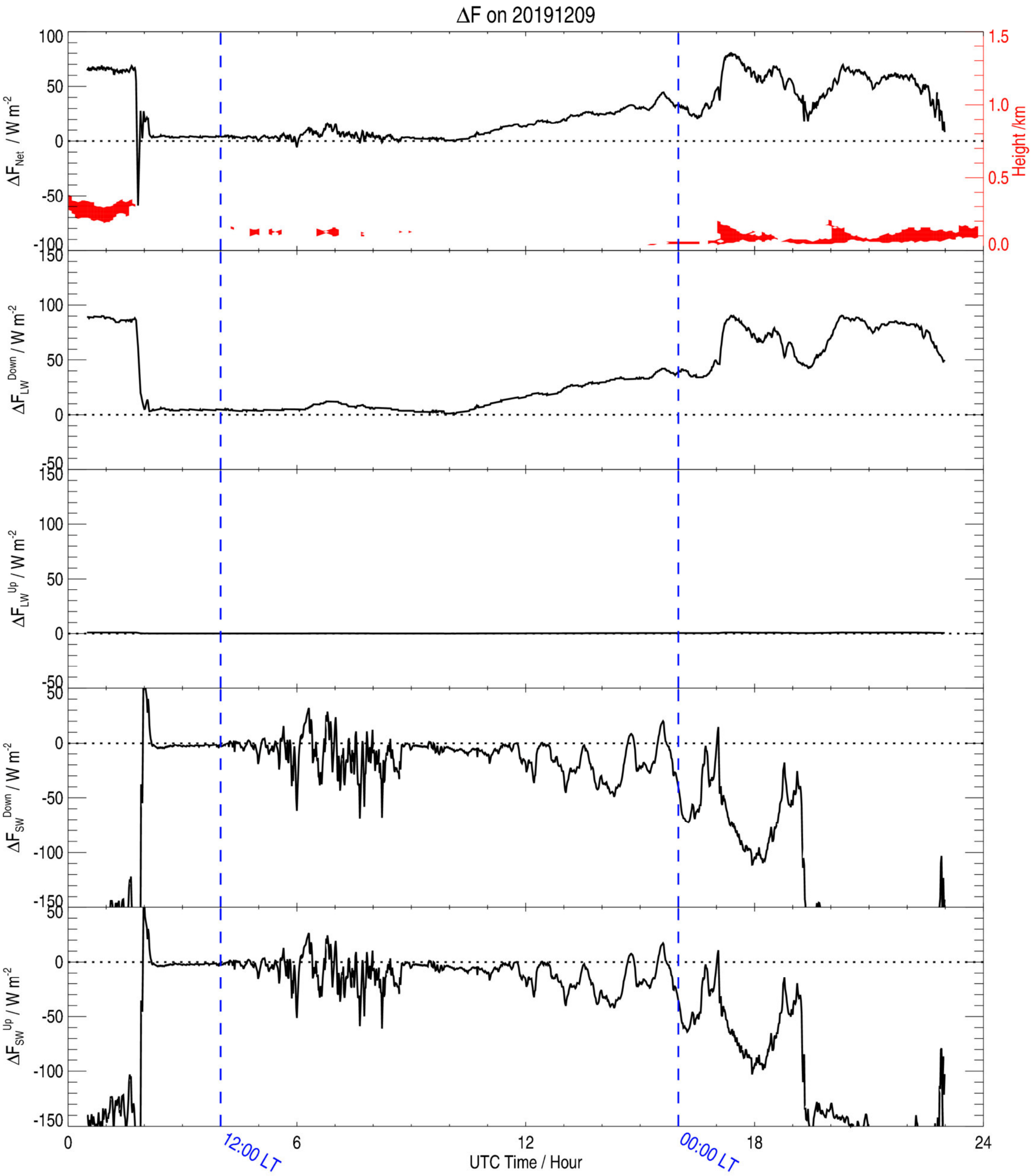

Figure R1: Time evolution (UTC, hour) of the cloud radiative forcing components (ΔF) (W m^{-2}) calculated on 9 December 2019: (from top to bottom) net, longwave downward, longwave upward, shortwave downward and shortwave upward. The SLW cloud layer (if present) is highlighted by a red area in the uppermost panel, with the height on the y-axis shown on the right. The 00:00 and 12:00 local times (LT) are highlighted by 2 vertical blue dashed lines.

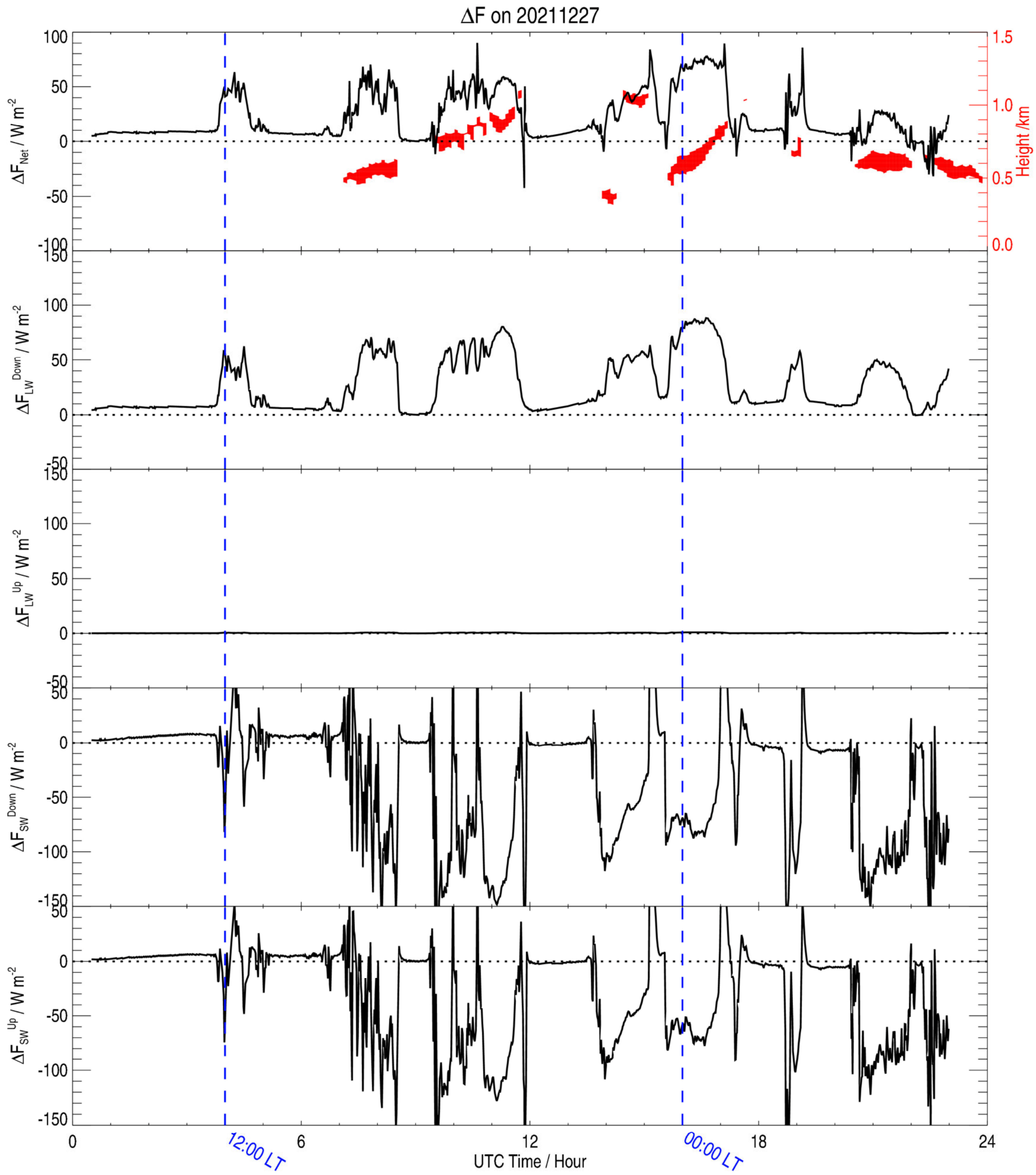

Figure R2: Same as Figure R1 but on 27 December 2021.

Now, if we consider the complete data set encompassing the 4 Decembers 2018-2021, the relationship between LWP (g m^{-2}) and ΔF_{net} (W m^{-2}) as seen in Figure R3 was shifted with respect to the estimates presented in the previous version of our paper (Figure R4). We note that there is no longer negative forcing irradiance (significant ΔF_{net} values are positive whatever the positive LPW values) which is now expressed as:

$$\Delta F_{net} = (-18 \pm 10) + 70 \ln(LWP) \quad (8)$$

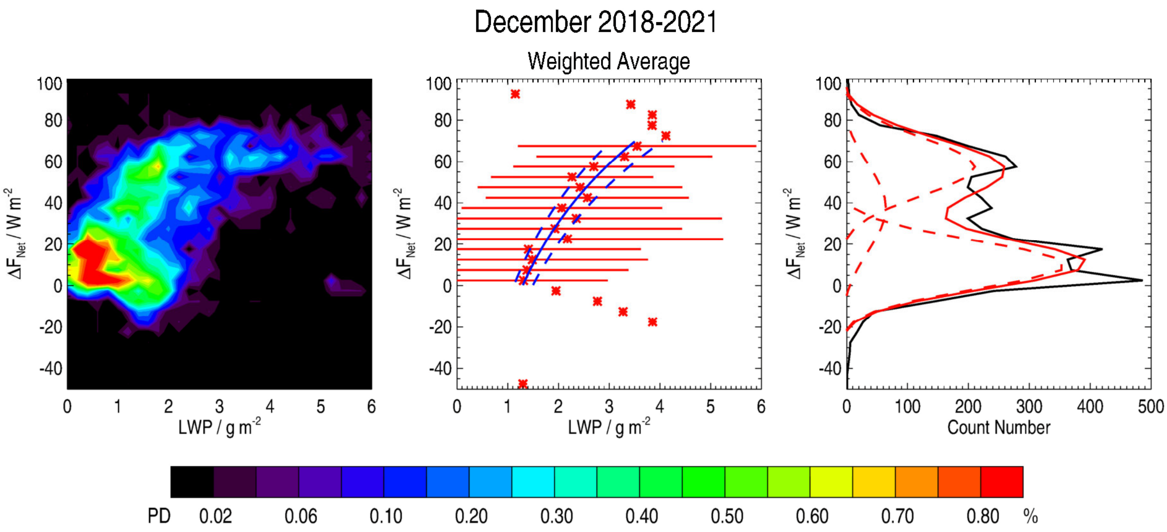

Figure R3: (Left) Probability Density (PD, %) of the net cloud radiative forcing (ΔF_{net}, W m^{-2}) as a function of Liquid Water Path (LWP, g m^{-2}) contained in the Supercooled Liquid Water clouds (SLWCs) above Dome C in December 2018-2021. The PD is defined in the manuscript. (Centre) Weighted-average LWP vs. ΔF_{net} with a fitted logarithmic function (blue solid) encompassing the significant points (2 dashed blue lines). Horizontal bars represent 1-sigma variability in LWP per 5 W m^{-2}-wide bin over significant points. (Right) ΔF_{net} as a function of count number per 5 W m^{-2}-wide bin (black solid line) with 3 fitted Gaussian functions (red dashed curves). The sum of the 3 Gaussian functions is represented by a red solid line.

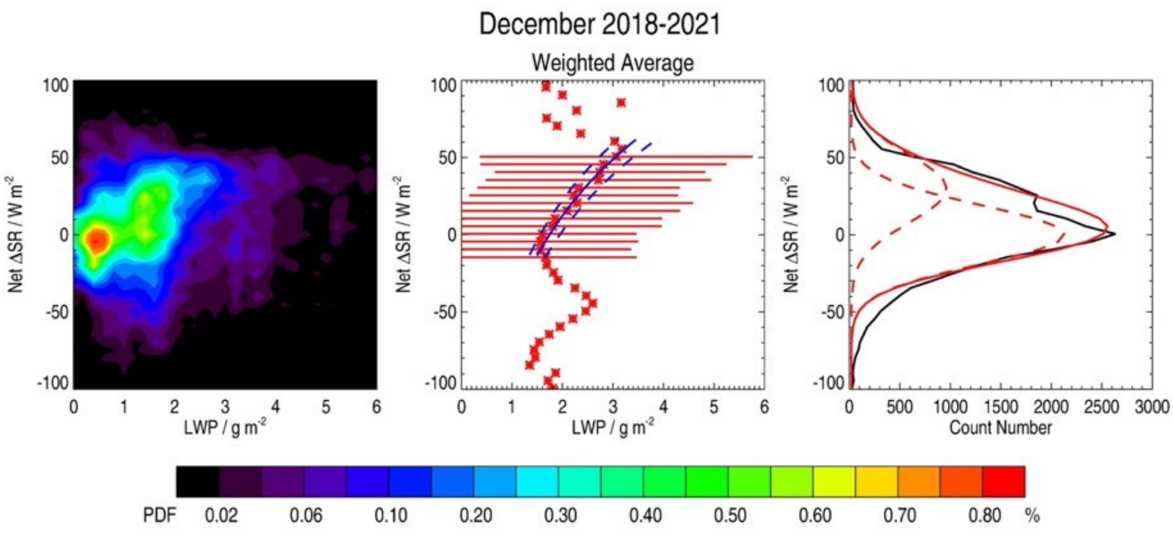

Figure R4: Figure presented in the very first version of the paper showing negative bias in ΔF_{net}.

And we have reproduced all the remaining Figures (R5-8) showing Probability Density (PD, %) of the cloud radiative forcing in the LW and SW downward and upward (W m^{-2}) as a function of Liquid Water Path (LWP, g m^{-2}) contained in the Supercooled Liquid Water clouds (SLWCs) above Dome C in December 2018-2021.

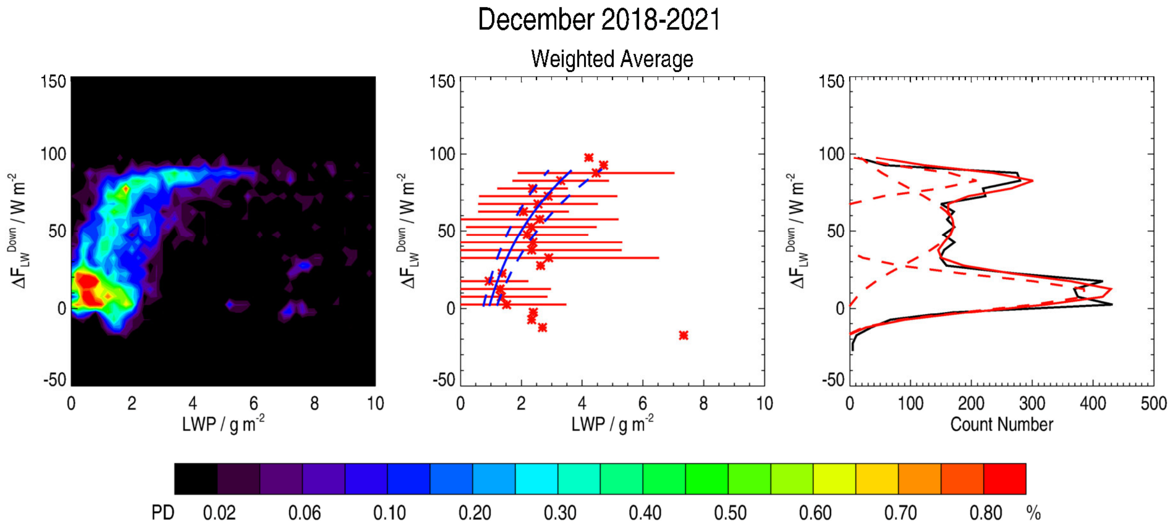

Figure R5: Same as Figure R3 but for ΔF_{LW}^{Down}.

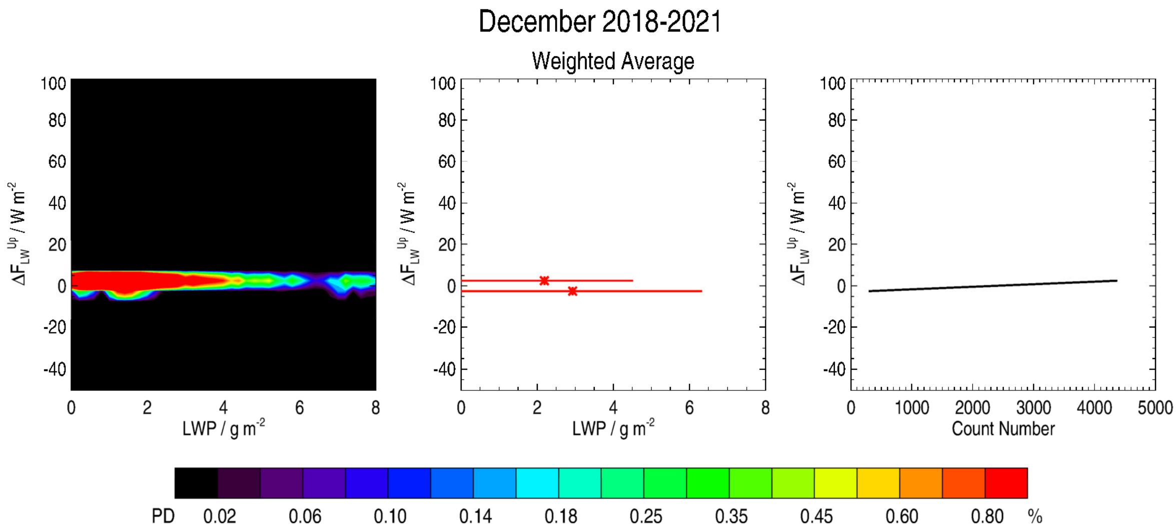

Figure R6: Same as Figure R3 but for ΔF_{LW}^{Up}.

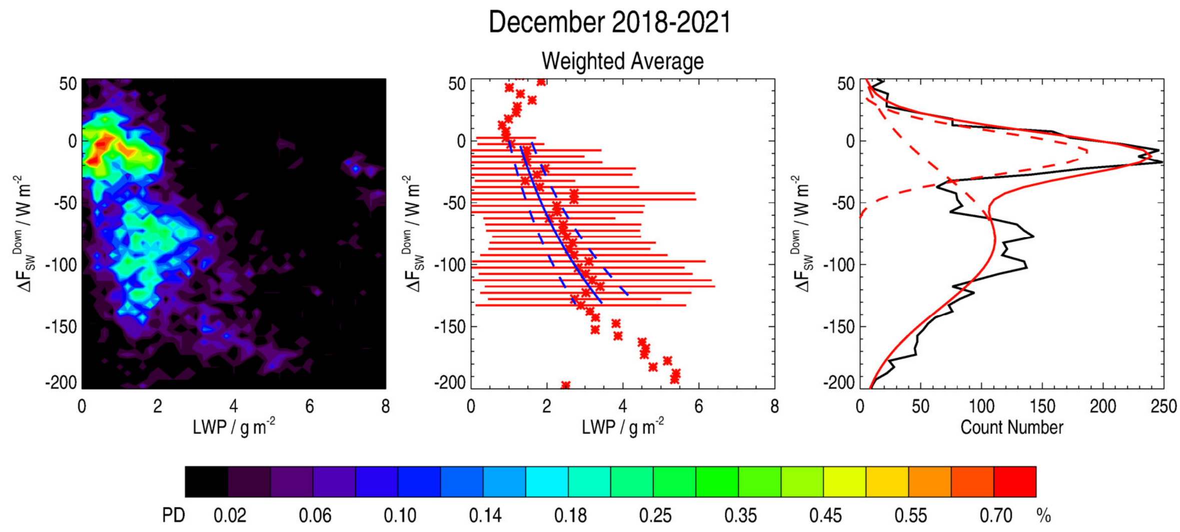

Figure R7: Same as Figure R3 but for ΔF_{SW}^{Down}.

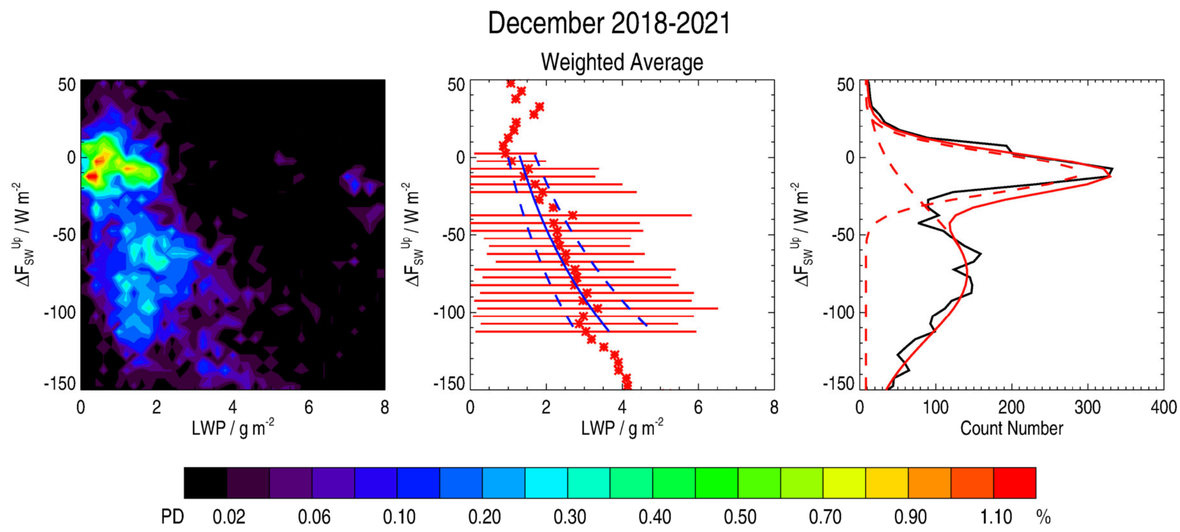

Figure R8: Same as Figure R3 but for ΔF_{SW}^{Up}.

For each T and ΔF dataset, the distribution of the total count numbers N_{tj} per 1°C or 5 W m^{-2}-wide bin ($N_{tj} = \sum_{i=1}^{M} N_{ij}$ with j = 1, …, N) can be fitted by a function $N(x)$, with x = T or ΔF, based on 2 to 3 Gaussian distributions as:

$$N(x) = \sum_{k=1}^{2 \text{ or } 3} a_k \exp\left(-\frac{1}{2}\left(\frac{x-\mu_k}{\sigma_k}\right)^2\right) + c \tag{9}$$

with a_k, μ_k and σ_k being the amplitude, the mean and the standard deviation of the k^{th} Gaussian function (k = 1, 2 or 3) and c is a constant. Table R2 lists all the fitted parameters (a_k, μ_k, σ_k and c with k = 1 to 2 or 3).

Table R2. Gaussian functions fitted to the $N(x)$ function for x = T (°C) or ΔF (W m^{-2}). Units of a_1, a_2, a_3, and c are in count number for T and ΔF; units of μ_1, μ_2, μ_3, σ_1, σ_2, and σ_3 are in °C for T and in W m^{-2} for ΔF.

x	a_1	μ_1	σ_1	a_2	μ_2	σ_2	a_3	μ_3	σ_3	c
T	15.0 10^3	-31.5	1.45	5.0 10^3	-28.0	1.65	0.5 10^3	-19.0	2.5	-9.1 10^{-6}
ΔF_{net}	371.7	10.0	11.5	74.6	37.6	21.1	220.8	57.5	14.1	-10.2
ΔF_{LW}^{Down}	415.5	10.0	10.4	189.5	53.7	24.2	227.1	82.9	7.0	-18.5
ΔF_{LW}^{Up}	-	-	-	-	-	-	-	-	-	-
ΔF_{SW}^{Down}	190.5	-10.1	17.2	113.0	-80.0	54.6	-	-	-	-1.9
ΔF_{SW}^{Up}	282.4	-10.1	12.8	133.8	-75.0	41.8	-	-	-	8.3

And a new logarithmic function of the form

$$x = \alpha + \beta \ln(\overline{LWP}) \tag{10}$$

has been fitted onto these significant points where the retrieved constants α and β are shown in Table R3.

Table R3. Coefficients of the relations $f(LWP) = \alpha + \beta \ln(LWP)$ for the temperature T or cloud radiative forcing ΔF. Units of T and ΔF, as well as of their corresponding "α" values are in °C and W m^{-2}, respectively; units of β are in °C g^{-1} m^2 for T and in W g^{-1} for ΔF; units of LWP are in g m^{-2}. The last column shows the range of LWP values for which the relation is valid. Note that $\alpha \pm \delta\alpha$ corresponds to the range of α values where the relationship is valid.

$f(LWP)$	$\alpha \pm \delta\alpha$	β	Valid range for T or ΔF	Valid range for LWP
T	-33.8 $\pm$ 1.5	6.5	$[-36; -16]$	[1.0; 14.0]
ΔF_{net}	-18.0 $\pm$ 10.0	70.0	[0; 70]	[1.2; 3.5]
ΔF_{LW}^{Down}	5.0 $\pm$ 15.0	65.0	[0; 90]	[1.0; 3.5]
ΔF_{LW}^{Up}	0 $\pm$ 5.0	0.0	$[-5; 5]$	[0.0; 6.5]
ΔF_{SW}^{Down}	30.0 $\pm$ 30.0	-130.0	$[-130; 0]$	[1.5; 4.0]
ΔF_{SW}^{Up}	30.0 $\pm$ 30.0	-110.0	$[-110; 00]$	[1.5; 4.0]

3. The figures are well described but the interpretation should be extended, e.g. what causes the effects of the single radiation components.

→ To summarize, the impact of SLWCs on single radiation components is:

- LW down: main term for the cloud-related impact. Order of magnitude: 0-80 W m^{-2}
- LW up: marginal impact since there is no relation with LWP, it is mainly dependent on T_s which results from various meteorological forcing
- SW down: a huge reduction of direct solar radiation, which can overpass 100 W m^{-2}, but is largely compensated for by:
- SW up: the very high surface albedo values result in a weak net SW radiation.

In conclusion, the driving term is the downward longwave irradiance.

Minor/Specific Comments

The page and line numbers refer to the pdf file: acp-2022-433-ATC1.pdf

1. The authors should be more precise in using specific terms. (i) "Radiative flux" is often wrongly used in literature. It describes a flux in units of Watt, but pyranometers and pyrgeometers measure flux densities in units of Watt per square meter. Either use the term "flux density" or, what is often used in the literature, "irradiance". (ii) Further use "surface albedo" instead of albedo. Albedo can also refer to the albedo of a cloud. (iii) Consider using the term "cloudless" or "cloud-free" instead of "clear-sky". The term "clear-sky" indicates an atmosphere that is also free of aerosols. (iV) "surface radiation anomaly" – anomaly sounds weird. Actually it is a "cloud radiative forcing", as used in literature.

→ In the revised version, we have modified all the terms as recommended by the reviewers into: "cloud-free", "irradiance", "surface albedo" and "cloud radiative forcing". See above "Main Comments, section 2"

2. P3L62-64: You should also mention the role of CCNs and INPs here.

→ We have inserted some information relative to CCNs and INPs.

The abundance of Supercooled Liquid Water (SLW, the water staying in liquid phase below 0°C) clouds depends on temperature and liquid/ice fraction. Furthermore, the nature and optical properties of the clouds depend on the type and concentration of cloud condensation nuclei (CCNn) and ice-nucleating particles (INPs). Bromwich et al. (2012) mention in their review paper that CCNs and INPs are of various nature and large uncertainties exist relative to their origin and abundance over Antarctica.

3. P5L99: "surface radiation" – I would prefer to use the term "surface irradiance" and symbols in Eq. (1) something like that: F_net = (F_down-F_up)_LW + (F_down-F_up)_SW.

→ We modified the terms, see above "Main Comments, section 2"

4. P8L187: What is a "regular" temperature profile?

→ We changed the term into "temperature profile".

5. P10L231-233: Give a reason for the variability. In SW it is clearly an effect of SZA.

→ The sentence referred to here was relative to a sometimes positive and sometimes negative cloud impact on the net radiation in the previous manuscript. With the new calculations presented in the revised version, we can see that the impact is now almost always positive (see Fig. R3), which seems consistent.

6. P10L239-241: What is the contribution of temperature and humidity on the differences in LW? That could be analyzed by radiative modeling.

→ To answer this question, it is necessary first to look at the values of the equivalent atmospheric emissivity ε_a used in the equations 4-7 above. The values of Integrated Water Vapour (IWV) observed at Dome C are very low even in summer, typical summertime values are between 0.8 and 1.2 kg m^{-2} (Ricaud et al., 2020). This corresponds to values of ε_a between 0.950 and 0.985, i.e. a relative variation of the order of 3.6%. On the other side, a variation ΔT of the screen-level (surface) temperature T_a (T_s) has a relative impact the downwelling (upwelling) longwave irradiance of the order of 4 $\Delta T/T_a$ (4 $\Delta T/T_s$), which amounts to around 1.6% per degree of ΔT. Given that observations of surface and screen-level temperatures reveal variations of several degrees, both in their diurnal cycle and from a day to another, we can conclude that the impact of temperature on longwave irradiance variations is larger than that of IWV.

We have thus inserted a new paragraph in the revised version that synthetizes our results.

7. P11L244-245: Spikes can be attributed to cloud edge effects, when direct fraction of the solar incident radiation and an additional diffuse contribution scattered from cloud edges falls on the radiation sensor.

→ This point is included in the new version of the manuscript.

8. P11L257: "The study is focuses on …" – already mentioned before. Skip it. Also details of binning were described before.

→ Removed.

9. P14L322: Don't mention binning details.

→ Removed.

10. P15L342-345: "Considering the SR vs. LWP relationship…" - I don't quite understand the connection with Table 3. If there is a mode that is centered around 0 W m^-2, then it probably refers to a low LWP.

→ Removed.

11. Sec. 5.2 on the Reference Surface Radiation and sastrugi effect: Here it is not clear to me, what the benefit of using ERA5 and CERES data is for this study. Remove this section and use radiative modeling to create your cloudless references.

→ Section removed regarding ERA5 and CERES, but we kept the discussion on the sastrugi effects on the surface albedo since it is a key component to characterize the solar upward irradiance.

12. P22L513: "a lower layer being made of liquid water and an upper layer being made of solid water" – I am sure this generally true for mixed-phase clouds. To my knowledge liquid cloud particles are mainly near cloud top (https://www.pnas.org/doi/full/10.1073/pnas.1418197111).

→ From literature (see e.g. Fig. 12.3 from Lamb and Verlinde (2011)) and LIDAR observations at Concordia (see e.g. Figure 1 of the present paper), liquid (low depolarization ratio) is below solid (high depolarization ratio) water in cold clouds above Concordia.

13. P22L519-522: The positive part in the SW is probably due to cloud edge effects rather than the presence of liquid and ice particles in the cloud.

→ Positive part is not significant in the new study.

14. P22L530: "during the local "night" at 00:00-06:00 LT" – should by polar day.

→ Yes. We modified the term into:

"at 00:00-06:00 LT when the sun is at low elevation above the horizon (24-h polar day),"

15. Sec. 5.6 on the potential radiative impact of SLWCs over Antarctica: The estimation of an Antarctica-wide radiative impact of SLWCc is based on the maximum net difference. How is the effect of SZA on F_net(SW) accounted for here, how the effect of seasonal dependent atmospheric profiles that determines the LW contribution? The 50 W m-2 is probably not a representing number for a larger area and time frame.

→ We have re-analyzed the results by considering a maximum of 70 W m^{-2} in the net cloud radiative impact (present analysis) that gives a slightly bigger impact compared to our previous analysis at the scale of the Antarctic continent. Our analysis does not require vertical profiles of temperature. Based on our study performed locally at Concordia in summer, we can estimate that, over the Antarctic continent, SLWCs have a maximum net radiative forcing rather weak over the Eastern Antarctic Plateau (0-7 W m^{-2}) but 3 to 5 times larger over Western Antarctica (0-40 W m^{-2}) maximizing in summer over the Antarctic Peninsula.

To conclude, this study showed that the major impact of SLWCs on net surface irradiance is an increase of downward longwave component. In the presence of SLWC, the attenuation of solar incoming radiation is almost compensated for by upward shortwave irradiance because of high values of surface albedo, whatever the solar zenithal angle. But the seasonality impact must be considered, since SLWCs are preferentially observed in summer.