Interactive comment on “Conceptual model of diurnal cycle of stratiform low-level clouds over southern West Africa”

Response to reviewer 2

Dear reviewer 2,

We thank the reviewer for his/her valuable and constructive suggestions, which led to significant improvements of the quality of our manuscript. Below we detailed how his/her comments are addressed in the revised version of the manuscript. The major corrections made in the manuscript and cited in this document appear in italic. All the typographic, orthographic, syntactic corrections detailed in the supplement were more than appreciated! We hope we included all of them correctly in the text; however, we must admit that we could not read three of them (see at the end of the response).

Major Comments:

1) Important to have consistency throughout. In the abstract the phrase "low-level stratiform clouds" occurs while in the title it is written as "stratiform low-level clouds". Because "low-level stratiform clouds" is used throughout the manuscript, a more consistent title would be "Conceptual model of the diurnal cycle of low-level stratiform clouds over southern West Africa".

We absolutely agree with the reviewer and the title has been changed.

2) A better initialism than "LLC" for "low-level stratiform clouds" would be "LLSC", and for three reasons. The first reason is that "stratiform" is an integral adjective in the clouds studied in this manuscript. A second reason is that to sound out in one’s mind "LLC" the word "stratiform" does not occur, so only "low-level clouds" appear, but one knows that "stratiform" is important so one has to insert the word into the "LLC" initialism, making it just a tad bit harder to read the paper. The third, and final, reason is that "LLC" is too close to "LCL", inviting confusion. In one place (at least) the authors mix them up too. Whoops!

We also agree with the reviewer; we actually used the initialism LLSC in one of the paper submitted at the same ACP special issue (Dione et al), and it make sens to be consistent with it. This will help the reader AND the authors not to mix LLC and LCL up.

3) Figure 2 must be perfect, yet it has a number of things that need to be improved.

In the figure caption the words "The greenish rectangles and triangles" occur. First, the figure looks to contain more blues than greens.

“Greenish” has been replaced by “Blue” in the legend.

Second, the horizontal advection symbol is neither a rectangle nor a triangle. As a result, this part of the caption is not helpful and needs to be cleaned up.

The shapes have been chosen according to the contribution of each term to the total local cooling, as a function of height. The radiative term is symbolized by a rectangle because it is constant with height. The turbulent term is symbolized by a triangle because it decreases with height. The horizontal advection is maximum at $Z^*=1$ but is half of its maximum value at surface and at $Z^* = 2$, so it is symbolized neither by a triangle nor by a rectangle, but by an appropriate shape corresponding to this profile. A sentence about the choice of the shape is included now in the legend (see below).

Second, the sentence in the caption that reads "The white dashed curves indicate the lifting condensation level (LCL)." needs more explanation in the caption than provided. It is not until Pages 13-14 that they are discussed. Something like "Each of the three LCL curves represents one scenario (of three) of CBL development found during the DACCIWA field campaign (Section 3.2.3)." should be added to the caption. Also, "Scenario 1", "Scenario 2", and "Scenario 3" should be used as labels for the dashed lines in the figure. See marked up manuscript.

Scenario 1, 2 and 3 have been added in the figure.

Each little rotation symbol in columns 2 and 3 of Figure 2 needs a precise meaning.
For example, based on the text, the clockwise rotating symbols in the middle of the
stratus layer in column 3 would seem to indicate downward mixing caused by cloud-top cooling. If this is correct, the symbols make sense; if this is not correct, this is an example of of these symbols causing confusion. The clockwise rotating symbols in the sub-cloud layer of column 3 seem to indicate downward mixing caused by the jet shear. Correct? If so, what does the counter-clockwise rotation symbol mean near the surface along the low level jet curve in column 2? Right above it is a clockwise rotating symbol so the juxtaposition of the two is confusing. Moreover, in a conceptual model the juxtaposition of two such symbols should be made perfectly clear in the text. In column 2 there is also a counter-clockwise rotation symbol at Z* = 1.5. What does this mean? According to its location along the low level jet curve, it might be taken to mean upward mixing due to shear. But in column 3 the rotation symbol at about Z* = 2.2 is clockwise, perhaps indicating downward mixing due to cloud-top cooling. If so, why is it placed right on top of the low level jet curve in column 3?

We are so sorry to cause the reviewer such a trouble trying to find a logic in the rotation of the symbol. We did not intend to put signification to the clockwise or counter-clockwise rotation symbol; they were put at places where turbulent mixing is known to be important. The results of our analyses do not allow to discuss the downward or upward mixing at different levels in the cloud or subcloud layers. We agree with the reviewer that the two rotations, clockwise and counter-clockwise, were puzzling. Only one rotation for the symbol is now used in Figure 2 and its signification is defined in the legend.

For Figure 2 to be most effective, every drop of ink on it needs a clear purpose and one that is described in the text and easily remembered.

We agree with all the suggestions of the reviewer; the figure has been modified and the caption is now: *"Conceptual model for the LLSC diurnal cycle over southern West Africa. The height is normalized by the LLSC base height (CBH) when the clouds form. The grey shades represent the LLSC (stratus-fractus or stratus) or cumulus cloud. The three white dashed curves indicate the lifting condensation level (LCL). Each of them represents one scenario (of three) of CBL development found during the DACCIWA field campaign (Section 3.2.3). The dark blue lines reproduce the vertical profiles of the wind with an indication of its maximum value for each phase. The various blue symbols at the bottom represent the processes involved in the potential temperature tendency equation (their shape is adapted to the contribution of each term to the local total cooling, as a function of height) (Section 3.1.2). H stands for the surface sensible heat flux and is symbolized by an orange arrow during the convective phase. The white rotating arrows symbolize nocturnal dynamical turbulence either due to the radiative cooling at the cloud summit or to the wind shear in the NLLJ."*

4) Figures 2 and 3 work really well together. Fun to read about them. The text on Pages 10 and 11 was a bit ambiguous in making perfectly clear that the curves in Figures 4 and 5 were averages over different phases. Or perhaps stated differently, it is disconcerting to see figures based on averages over different phases when the point of the paper is a conceptual model of the distinctness of the phases themselves. Figures 4 and 5 must contain averages over the four distinct phases to be most effective, even if some of the averages from one phase to the next are similar. All in all, Figures 4 and 5 were not intellectually satisfying, especially in comparison to Figures 2 and 3.

The Figures 4 and 5 objective is to quantify the processes involved in the air saturation (so before the stratus phase), this is why we focus here on the stable and jet phases. Adding the same figures for the stratus phase would add the difficulty to estimate the latent heat release due to condensation. This can not be estimated since we do not have the liquid water content for low level cloud only (we do have LWP but some higher clouds are often present). The radiative term would also be very difficult to estimate.

We agree with the reviewer that these figures for the stable and jet phase separately would have been much more satisfactory. But we really wanted to show, in this paper, the results over the different DACCIWA sites as much as possible, in order to generalize this conceptual model, first established with data acquired at Savè (the most instrumented site), to other locations in southern west Africa. Separated analyses for Stable and Jet phases were done by Adler et al (2019) for Savè because the number of radiosoundings were sufficient for most of the IOPs (1 radiosoundings every 1.5hrs). The number of radiosoundings was not sufficient at Kumasi (1 radiosoundings every 3hrs) which prevents separated analyses for the two phases and the start of the Jet phase has not been established at this site by the fuzzy method detailed in Dione et al, 2019.

We made clear in the text page 10 and 11 that these two figures are averages over Stable and Jet phases.
Page 10: *"Figure 4 shows averaged vertical profiles, over stable and jet phases, of specific humidity and temperature contributions to the total change in RH at the Savè and Kumasi sites. The height is normalized by the cloud base when the stratus form. The median value of the cloud-base at Savè and Kumasi are 227 m a.g.l. and 137 m a.g.l., respectively (Kalthoff et al., 2018). At Savè, the cooling causes at least 80 % of the RH increase. Adler et al. (2019), who analyzed the moistening for separated stable and jet phases at Savè, pointed out a weak moistening during the stable phase which is almost compensated by a drying occurring during the jet phase, leading to a 20 % contribution of the moisture to the increase in RH at the end of the two phases (Fig.4a)."*

Page 11*: " The vertical profiles of all these terms, averaged over stable and jet phases, are presented in Figure 5. If such an analysis was performed separately for stable and jet phases at the Savè site (Adler et al., 2019) (not shown), it is however not feasible at the Kumasi site because, among other reasons, the MI and NLLJ arrival times were not established, so that the start of the jet phase is unkonwn."*

Minor Details:
0) A marked-up manuscript is being returned to the authors. It may contain detailed comments that they may find useful. The handwriting on the manuscript is not always so good, which is unfortunate. My apologies! The more important points in the marked-up manuscript now follow.

1) The first paragraph on Page 5 (Lines 1-11) is not relevant to the main story of the manuscript and can be removed. The sentence on Lines 6-8 was relevant and can be moved to Page 16, Lines 20-25, as additional factors to consider.

We agree that the paragraph does not respect the logic of the introduction. So we moved it in the conclusion (penultimate paragraph) and removed two of the references which were not directly linked to LLSC studies. The paragraph is now : *"A factor to also consider in the study of LLSC diurnal cycle is the aerosol effect in the context of rapid and significant socioeconomic changes that are happening in the southern West Africa (Knippertzet al., 2011). Deetz et al., 2018 performed highly resolved process study simulations for 2–3 July 2016 with COSMO-ART to assess the aerosol direct and indirect effect on meteorological conditions over southern West Africa. They find that MI and stratus-to-cumulus transition are highly susceptible to the aerosol direct effect, leading to a spatial shift of the MI front and a temporal shift of the stratus-to-cumulus transition with changes in the aerosol amount. On the other hand, aircraft measurements of aerosols and clouds over southern West Africa during the 2016 summer monsoon show pollution and polluted clouds across the whole region (Taylor et al., 2019, Haslett et al., 2019)".*

2) The legends of color dots in Figures 1a and 1b need labels.

The labels have been added to the legend of color dots.

3) "Q" is not defined in Eq. 1 on Page 10.
The definition of Q has been added on page 10: *" where u, v, w are the wind components, ρ the mean air density, Q the net radiation flux,..."*.

4) The authors need to rethink their use of "the day after." This finally became clear on the bottom of Page 11. Here, it is stated that stratus occurs from 2200 UTC on day 1 out to 0500 UTC on day 2. In this case "the day after" on Line 26 would mean there is a day 3. Maybe just using "day 1" and "day 2" would be simpler and more exact.
We thank the reviewer for taking note of this mistake. The sentence has been modified as follow: *"The stratus appears after 2200 UTC on day D and, for most of the cases, between 0000 and 0500 UTC on day D+1. The breakup occurs before 1500 UTC on day D+1."*
In the abstract, the sentence *"The LLSC, inaccurately represented in the climate and weather forecasts, form in the monsoon flow during the night and break up the day after,..."* is now : *"The LLSC, inaccurately represented in the climate and weather forecasts, form in the monsoon flow during the night and break up during the following morning or afternoon,..."*.

5) The change in significant digits on Page 11, Lines 8-21, was a bit jarring.

The significant digit is now uniform in the text.

6) Not sure that the sentence on Page 13, Lines 13-15, means exactly the same thing
as the sentence on Lines 3-5 of the Figure 7 caption.

We do agree with the reviewer that the standard deviation of the cloud fraction within the time it is estimated (30 min) does not mean anything. The right information was given in the legend and the

sentence in the text is now: *"The half-hourly standard deviation of the cloud base, the cloud fraction (percentage of cloud base below 1000 m a.g.l. over 30 minutes) and the difference between cloud base height and LCL are indicated on the bottom panel."*

7) Page 13, Line 12: Never seen the word "summit" in this context. How about "radar cloud top"? If not "radar cloud top" this word needs to be defined.

"Cloud top" was what we meant. "*Summit*" has been replaced by "*top*" everywhere in the text.

8) The words "most likely" and "can" showed up a bit on Page 16. These are weak words in this context because they imply a weaker conceptual model. They should be removed from the manuscript in some way.

Yes, this comes from a personal tendency not to be too peremptory. I removed this verbs which weaken the conclusion.

9) Figure 3: The x-axis tick marks must represent hours. So, the x-axis labels should have the units of time in them. Perhaps "(hr)"?

We agree with the reviewer that the unit is missing. The unit "(hr)" has been added to the x-axis label.

10) Figures 4a and 4b: The y-axis tick mark labels should have the same number of significant digits.

The two "RES" lines in Figure 4b should have the same color because they both represent residual curves. To distinguish between them, one can add (TURB) to "RES" in the left column legend and (TURB+RAD) to "RES" in the right column legend.

The figure has been modified as suggested.

And again, one set of curves for each phase would be much more effective.
See response to major comment #4.

11) Figure 7 visible and infrared images: The features in the visible and infrared images do not seem to line up. Is the because their fields of view and their orientations do not line up? The infrared images seem to have a color bar at the bottom of the images whereas the visible images have no grey scale. It would be helpful to have visible and infrared images with the same fields of view and the same orientation relative to north (top), south (bottom), west (left), and east (right) relative to the page. Also, some sort of grey and color bars with labels would be helpful. These changes would make the images work better together.

As indicated in the section 2, the visible images were full sky images whereas the aperture angles for the infrared camera were 43° times 32°, which corresponds to a 158 m times 114 m area at a height of 200 m. To make this information clearer in figure 7, and following the suggestion of the reviewer, we added a black rectangle in the visible images corresponding to the area of the infrared images.
Concerning the color scale, the infrared camera is a security camera. Up to now we failed to establish a simple law between the color scale and a brightness temperature, this is why we only use it in a

qualitative way. The color scale and the brightness temperature are now qualitatively linked in the legend; this information was sorely lacking. The legend is now: *"(a) 8 July (IOP 8), (c) 27 July (IOP 14), and (e) 18 July (IOP 11) illustrate scenarios 1, 2 and 3, respectively. The temporal evolution of the cloud base height (red dots) and cloud summit (grey dots) and LCL with its uncertainty (black line with grey shading) are presented in the top panels. The LCL uncertainty is based on the uncertainties of the temperature and humidity sensors used for the LCL estimation. The temporal evolution of the cloud fraction (blue line), the standard deviation of the cloud base over 30 minutes (black line), and the difference between LCL and CBH (black dashed line) are presented in the bottom panels. The vertical green dashed lines indicate the stratus onset and breakup times. The vertical red lines indicate the times of the visible and infrared cameras pictures presented on (b), (d), and (f) for IOP 8, IOP 14 , and IOP 11, respectively. The times are 0814 and 1028 UTC on 8 July, 0718 and 1214 UTC on 27 July, and 0702 and 1036 UTC on 18 July. The color scale for the infrared images (indicated at the bottom of the images) ranges from blue for colder brightness temperatures, to white for the warmer brightness temperatures. The black rectangle on the visible images indicate the area corresponding to the infrared images. The white dot in the infrared images, at 1214 UTC on 27 July and 1036 UTC on 18 July, is due to the sun and is located at the center of the solar disk."*

By "incertitude", is "uncertainty" meant"? If so, why not use "uncertainty"?

Sorry we meant uncertainty. The changes have been done.

About the corrections in the supplement:
P5 l12 and P15 l12: The reviewer suggests "the most important details" instead of "the most important lessons". "most important" and "details" seemed contradictory to us, so we did not make the change.

P12 l3-5 and P15 l15-20: we could not read the reviewer's comments in the left margin.