Response to Anonymous Referee #3

We thank the reviewer for the helpful and detailed comments. We appreciate the time she/he took in reviewing our paper. Comments are summarized and responses are in italics below.

General comments:

One of the biggest issues with this study is that it uses the box model to fine tune a calculated updraft velocity based on the observations, and then, as far as I understand, compares it to the effective supersaturation determined by the same box model using the same trajectory. It is therefore not surprising that the comparison with the model improves when the same model is also used to predict all the parameters. Of course we can still learn a lot from the model output, but the text should clearly state which parameters were derived from the model versus derived from basic atmospheric assumptions. This would allow the reader to understand the significance of the findings.

This lack of clarity is mostly because of two technical issues. The first is that this study relies heavily on the results from the authors' previous study, but it does not explain how all the parameters were calculated. This makes it difficult for the average reader to follow how an estimated updraft velocity is different from a model updraft velocity, for example. (Note - to me, both of these values are modelled, only one uses a much more sophisticated model than the other.) This is not appropriate for a stand-alone paper and can be easily remedied by additional text briefly, but thoroughly, describing the key parameters derived in the previous study and used in this one. The second technical issue is that the notation is difficult to follow and I found myself needing to make a table just to keep track of all the variations of the parameters. If the authors could provide a table that logically grouped the parameters based on their origins, this would greatly increase the readability of the manuscript. Based on this, I would recommend that this paper be accepted subject to the important, but minor, revisions stated above, and the specific comments below.

We agree that it might be more useful to have the whole explanation of the parameters effective peak supersaturation and estimated updraft velocity in this manuscript. Therefore, we added the following descriptions:
to Section Effective peak supersaturation: "The SS_{peak} was retrieved from the measurements at the JFJ as follows: 1) the activation threshold diameter was determined from the measurements of the total and interstitial number size distributions 2) the aerosol hygroscopicity was obtained from the simultaneous CCNC measurements 3) the activation threshold diameter was combined with the aerosol hygroscopicity, and the estimated cloud base temperature to infer the effective peak supersaturation. A relative uncertainty of about 30% was estimated for SS_{peak}. A detailed description how the SS_{peak} was estimated from the measurements performed at the JFJ can be found in Hammer et al. (2014)."

Following your suggestion, we added the following table to Sect. 2:

Table 1. List of important symbols

Parameter	Notation
General parameters	
SS	supersaturation
SS_{peak}	effective peak supersaturation (Hammer et al., 2014)
SS_{crit}	critical supersaturation (Köhler, 1936)
w	updraft velocity
Measured parameters	
w_{act}^{meas}	measured updraft velocity
Estimated parameters	
SS_{peak}^{estim}	estimated effective peak supersaturation derived from measurements (see Sect. 2.3.1)
w_{act}^{estim}	estimated updraft velocity derived from measurements and topography (see Sect. 2.1.2)
Modelled parameters	
SS_{peak}^{mod}	modelled effective peak supersaturation
SS_{peak}^{ref}	effective peak supersaturation obtained from the reference model simulation
SS_{mod}^{max}	maximum relative water vapour pressure between the model initialization point and the JFJ
w_{act}^{mod}	modelled updraft velocity
w_{mod}^{divX}	modelled updraft velocity divided by X
w_{mod}^{mulX}	modelled updraft velocity multiplied by X
SS_{peak}^{fluc}	modelled effective peak supersaturation applying the real-time fluctuations
$SS_{peak}^{fluc,sin}$	modelled effective peak supersaturation with a sinus function

Specific comments:

Page 25972, line 12

You should state that you are assuming that none of the water is lost to precipitation and reasons to back up this assumption.

We added: "… before cloud formation. As in (Hammer et al., 2014), it was assumed that water removal due to precipitation was negligible.

Page 25974, line 11

What is the estimated time between droplet activation and the observation site? Would you expect coalescence to occur?

The median cloud base height was calculated at about 270 meters below the station. Taking the median estimated updraft velocity of 0.8 m/s, a transit time of 216 seconds results. Therefore, coalescence can't be ruled out but the transit times are pretty short, so we don't think that it has a big effect.

Page 25972, line 26

What is the basis of this wet adiabatic lapse rate? Are there no observations that you can use?

No, unfortunately there are no measurements available for retrieving the lapse rate. Due to the steep slope towards the North side (its basically a crumbly rock wall) it is not possible to mount any instruments there. There are also few meteorological stations in the area, and those that exist tend to be within a valley, or located in other places where the complex terrain dictates that they would not be influenced by the same air masses as those approaching the JFJ. For example, during the CLACE campaign in 2010 there was a ceilometer and a windprofiler installed at a site just below the Jungfraujoch. The study of Ketterer et al. (2014) showed that despite the proximity, the air passing over this site was not reaching the JFJ

Page 25976, line 7

The last statement on this line seems unintuitive. Normally one would think that if your model does not account for latent heat, then the wet adiabatic lapse rate would be the one that would be unnecessary.

The model runs from a pre-calculated temperature trajectory. Since latent heat release during condensation is not accounted for in the model (i.e. the temperature trajectory is not modified during the calculation), it needs to be accounted for in the trajectory. Therefore we use the wet adiabatic lapse rate.

Page 25977, line 5
A brief, but thorough, description of the calculations used to determine SSpeak from measurements should be in included here. It is unfair to the reader to expect that they have the manuscript from the previous study readily available.

We answered this comment above in the general comments.

Page 25978, line 13
How does using an average κ affect your results? It is unclear from the previous description that you are even using a varying κ. For this reason, it is important to include a description of your calculations, as mentioned above.

To make the section investigated parameters clearer, we rearranged some sections as follow:

- *Section "The effective peak supersaturation" was put as a new section after observational data*
- *In Section "Investigated parameters" we put "Simulated small-scale temperature fluctuations" as a subsection.*
- *Added a new subsection for "Hygroscopicity parameter"*

We added in Section "Modelled updraft velocity": "The modelled updraft velocity, w_{act}^{mod}, was used for the reference model simulation (see Sect. 2.4). This parameter, w_{act}^{mod}, was then varied to investigate the sensitivity of the updraft velocity on SS_{peak} (see results in Sect. 3.2)."

We added in Section "Aerosol- and updraft-limited regimes": "Thereby, the aerosol number concentration and size was varied by ±15% to investigate the sensitivity of the aerosol- and updraft-limited regimes on SS_{peak} (see results in Sect. 3.2)."

For the reference simulation we use a constant kappa, for the sensitivity tests we vary kappa to answer exactly this question – what the influence of kappa on the results would be (Fig 7). We added into the new section "Hygroscopicity parameter": "The hygroscopicity parameter, κ, stays rather constant over time at the Jungfraujoch at around 0.2 (Juranyi et al., 2011).To investigate the sensitivity of κ on SS_{peak}, a typical κ value for an aerosol size distribution with a larger fraction of organics (κ=0.1; Dusek et al., 2010) and for a continental aerosol (κ =0.3; Andreae et al, 2008; Pringle et al., 2010} was used (see results in Sect. 3.2). It is important to note, that the studies (Hammer et al., 2014a} and (Hammer et al., 2014b} revealed only a small influence of the κ-value on the calculated SS_{peak}."

Page 25979, line 7
Please expand on why these two updraft velocities are so different. This is a very important point since the remainder of the paper only relies on the modelled updraft velocity.

We added: "… than the estimated w_{act}^{estim}. As discussed in Hammer et al. 2014, The reason that the modelled Wact is much lower than the estimated value is possibly due to the air mass being accelerated as it passes through the narrow pass where the JFJ is located. This may lead to higher windspeeds being measured at the JFJ than those which were actually present when the cloud was formed at a lower altitude. To investigate the sensitivity …"

Page 25979, line 12
It is not surprising that the modelled data points are closer to the model simulations for the median case. It is true that the signal is clearer between SSpeak and w than in the previous study. However, the results presented here reflect the model, and in fact, our previous understanding of updraft velocity and supersaturation. This Figure does not really reveal any new understanding that is not already represented in the model. Figure 4 Since you are studying the effects of updraft velocity on peak supersaturation, the axes on this Figure should be reversed.

The point of Figure 4, was to show that the improved agreement between modelled and estimated peak SS suggests that the estimated wact is indeed too high. We agree that this was not clearly stated in the text, and have now added "…which is related to SSpeak. The fact that when the model is constrained to reproduce the observed number of droplets, a lower updraft velocity is found, causing a better agreement between modelled and estimated SSpeak, suggests that the updraft velocity *estimated from wind speed measurements at the JFJ is indeed overestimated." We have left the axes in the same configuration so that the figure may easily be compared with that of Hammer et al 2014.*

Page 25979, line 11
How was SS_{estim}^{peak} derived from measurements?

We added: "…SS_{peak}^{estim} (derived from measurements; see Sect. 2.3.1)."
as we added a description about SS_{peak}^{estim} according to the general comments.

Page 25979, line 19
Shouldn't the black lines by definition run through the green points since they are the median? While the black lines do seem to fit the green points better, the residuals are by no means centred around zero. The bias in the fit, and possible sources, should be discussed in this section.

It is possible that there has been a misunderstanding here. The black lines were calculated by running the model with number and size and kappa values representative of the 25 and 75th percentile of those observed, and the median. The model, using these values as input, was run for a range of updraft velocities, yielding the three lines in Fig 4. The observed points on the left hand side of the plot, showing low peak supersaturations at relatively high updraft velocities in comparison with the three modelled lines, result from times when the aerosol number was high (i.e. above the 75th percentile), preventing a high supersaturation from being reached. Likewise, on the right hand side of the plot, lower aerosol numbers (below the 25th percentile) would lead to the systematic overestimation displayed by the three lines. The variation of Kappa provides further scatter.

We have changed the description slightly to make this clearer:

"The black curve in Fig.4 represents the box model simulations of SS^{mod}_{peak} obtained by running the simulations for a range of constant updraft velocities. In the upper line, the aerosol size distribution was chosen so that the number and sizes of the aerosol and k value were representative of the 75th percentile of those observed during CLACE 2011. The bottom line was calculated similarly using aerosol properties representative of the 25th percentile, with the middle line calculated using aerosol properties representative of the median.

Page 25979, line 27
The points shift down in your current Figure.

We changed it to: "…the points shift substantially closer towards the black line, …"

Page 25981, line 7
Was κ also kept constant over size?

Yes, however this text fragment is deleted due to the answer to another reviewer.

Section 3.3
These results are really quite interesting. It would be worthwhile to consider moving this section earlier so that it is not passed over by an inattentive reader.

Actually, we would like to end the paper with one of the main result, which is Section 3.3. Therefore, we would like to keep it here but added the following to the abstract to give the results more weight: "Furthermore, there is a maximum of influence from turbulence on SS_{peak} between 0.2 - 0.4%. Simulating the small-scale fluctuations with several amplitudes, frequencies and phases, revealed that independently on the amplitude, the effect of the frequency on SS_{peak} shows a maximum at 0.46 (median over all phases). It was found that an increase in amplitude of the small-scale variations in the cooling rate, can significantly alter the CCN activation."

Page 25984, line 4
To which of the modelled values are you referring?

We changed it to: "… showed that for small w_{act}^{mod} the model was slightly underestimating the SS_{peak}."

Page 25984, line 5

This is really quite remarkable. What percentage of the points now fall within the 25th and 75th percentile lines?

We changed this as follows: "… slightly improves the SS^{fluc}_{peak}–w^{mod}_{act}-relationship at lower updraft velocities as can be seen in Fig. 9. 44% of all the data points are now lying within the 25th and 75th percentile range (compared to 41% before) and the other points are also much closer to the band."

Technical Comments

Page 25972, line 15
Change to "the ideal gas law and the Clausius-Clapeyron equation".

Page 25974, line 21
Change "can not" to "cannot".

Page 25975, line 23
Remove the comma between "that" and "which".

Page 25976, line 3
Change "while" to "where".

Page 25976, line 9
Change "was ranging" to "ranged".

Page 25976, line 16
Sentence should be "According to Köhler theory".

Page 25978, line 9
Consider changing the title of this section to "Reference model for sensitivity analysis" so that the reader can easily refer back to this section later.

Page 25978, line 12
This sentence should read "For this purpose" if you are referring to the reference simulation.

Page 25979, line 1
Figure 4 is mentioned before Fig. 3.

Page 25984, line 17
Change wording to "is faster than the time".

Page 25984, line 18
Remove "also" from the sentence to make it less awkward.

Page 25984, line 25
Consider removing "being able" from the sentence.

Page 25985, line 18
Change "indicates" to "results in" or "causes".

Page 25985, line 22
Consider changing the sentence to "particle size had a stronger influence on".

Page 25986, line 7
Remove "presumably" from the sentence.

Page 25986, lines 10-11
Consider changing the text to "are more strongly influenced by small-scale varations. The decreasing influence..."

Page 25986, lines 16-17
The present tense should be used to emphasize the results.

Page 25986, line 22

Change the text to "independent of the amplitude".

Thank you for all these technical comments. We applied all of these in the text accordingly.
Page 25975, line 17
To what fluctuations are you referring? This sentence is vague.

We changed it to: "To investigate the importance of the small-scale fluctuations of SS_{peak} to the decrease …"

Page 25976, line 25
Your wording of "corresponds to the SS_{mod}^{max}" suggests that this variable has been used before, whereas you are actually introducing it here.

We changed it to: "is expressed as SS_{mod}^{max} …"