

Interactive comment on “A broad supersaturation scanning (BS2) approach for rapid measurement of aerosol particle hygroscopicity and cloud condensation nuclei activity” by H. Su et al.

### **General comments**

The authors present a new way of measuring the critical water vapour supersaturation required for activation of particles, termed broad supersaturation scanning (B2S) method. This new approach enables (according to the authors) fast measurements and easy data analysis, which can be implemented, with simple technical adjustments, to existing (and broadly used) instruments such as the DMT-CCNC. The method may be used for long-term measurements of atmospheric aerosols.

The novel approach for the B2S method is very interesting and the results from model simulations accompanied by measurements with a nano-CCNC give good support for the interpretations and conclusions made in the paper. As emphasized by the authors, there is a need for fast and well-controlled measurements of the critical supersaturation, both of ambient aerosols as well as for laboratory generated aerosols.

Why is the method termed *broad supersaturation scanning* (B2S)? As I understand, the measurement of the whole  $S$  distribution is instantaneous? What is the scanning part of the method? Could there be a more suitable name for the method?

To simplify and make the concept of B2S more approachable for the reader, the authors exemplifies and makes comparisons with the commercially available CCNC from DMT, which I think is good in general. However, the DMT-CCNC is mentioned to a degree where one expects to see results from experiments using the same instrument. Therefore, I suggest the authors to remind the reader that the B2S-method is tested only with the nano-CCNC (for example in the first paragraph in the Methodology section when the concept is introduced).

I further suggest that the authors include a table of nomenclature and missing equations, the latter may be placed in the supplement.

In general, the paper is well written and concise, however in some sections a more descriptive text would be appreciated. I have a few comments that the authors should address prior to publication.

### **Specific comments**

Page 9714, line 25: Its desirable to add references for the two methods for determining CCN activities.

Page 9715, lines 3-16: The reason for developing and using the new approach is, as this paragraph declares, that a fast scanning of  $S$  is important for ambient measurements. However, the authors could also emphasize that there is a need for a method measuring rapid changing laboratory generated aerosols.

Page 9715, line 17: Please clarify if the measurements are supposed to be performed for size-resolved measurements.

Page 9715, line 19: Specify “infinitely small”.

Page 9715, line 22: The author states that “..., B2S-CCNC may be **built** with simple modifications of existing DMT-CCNC.”. As I understand, no modifications are needed of the instrument. Instead, a change in settings of the aerosol-to-sheath flow ratio is implemented. Please, clarify if the instrument need a change in settings, or modifications of the hardware and/or software, either in this part of the manuscript or later (e.g. at page 9716, line 26).

page 9716, line 5:  $S_{tube}$  is stated as (and shown in the figure) a function of  $r$ . Due to the relevance of  $S_{tube}$  in the analysis as well as future use of the B2S-method it is desirable to include the function in the paper or in the supplementary material.

page 9716, line 20: Please clarify what you mean by “The interval of  $S_{tube}$  scans determines the uncertainty of  $S_{aerosol}$ .” Do you mean the number of  $S$ -steps in a spectrum?

page 9716, line 26: (1) The concept of the approach is to “make use of the whole  $S$  distribution inside the activation chamber”, changing the aerosol-to-sheath flow ratio. The sheath-to-aerosol flow rate is preferably set to 10 for the DMT-CCNC (or aerosol-to-sheath=1/10). During measurements this ratio can be adjusted, for low concentrations to get sufficient counts, and for high concentrations to minimize coincidence in the OPC. How will low vs. high concentrations affect the B2S-method performance? Are there wall-losses, buoyancy or other effects to account for when changing the aerosol-to-sheath ratio?

Page 9717, lines 2-4: (2)  $F_{act}$  is here “calculated by integrating the activation fraction function  $g(x)$  over the cross section of the aerosol flow...”. Particles in the centerline ( $r=0$ , subjected to a higher  $S$ ) should have a different flow rate than particles closer to the wall (subjected to decreasing  $S$ ) due to the parabolic velocity condition in the instrument. Has this been considered and how will this affect the results of  $F_{act}$ ? Will it also affect the time resolution of the instrument, if central and peripheral parts of the flow, corresponding to different critical supersaturations, have different residence times in the instrument?

(3) How will  $F_{act}$  be affected by doubly/multiply charged particles? For the nano-CCNC the problem of doubly/multiply charged particles is minor. However, for measurements of ambient as well as laboratory-generated particles of larger particles this issue has to be taken into account. It would be desirable and give more credibility of the method to include a discussion and/or modelling results concerning this issue.

(4) Depending on size chosen by a DMA, the broadening factor will be less or more. Usually, this is reflected in the resulting  $S$ -scan from the CCNC (by a more or less steep slope). How will the broadening factor affect the results of the  $F_{act} - S_{aerosol}$  relationship? Is there a certain size interval/range where the B2S method is applicable? Is there a limit in the sheath to aerosol flow ration, below which the assumption of the DMA broadening is insignificant? What would be the authors’ recommendation?

I lack a discussion and/or modelling results regarding sources of errors (including the issues listed above: (1) effect of changing the aerosol-to-sheath ratio, (2) different flow rates for particles in different parts of the laminar flow, (3) influence of doubly/multiply charged particles, and (4) effects of the broadening factor from the DMA). I suggest a section for discussing uncertainties and errors.

Page 9717, line 15: Equation (2) is valid for  $\kappa > 0.2$  derived from CCNC measurements (according to Petters and Kreidenweis, 2007), and if small numerical errors are acceptable it can be used for lower numbers of  $\kappa$ . It would be useful for the reader if the authors could

comment on this. For example, will this affect the results from the measurements (Figure 6 (c)).

Page 9718, lines 8-9: According to the authors, the adjustment of  $S_{max}$  may be performed by changing the temperature gradient ( $\Delta T$ ) in the flow tube. Will the performance be affected by a change in  $\Delta T$ ? I.e. is the performance the same for low and high  $\Delta T$ ?

Page 9718, lines 11-16: Here the authors state that size-resolved CCN measurements can be performed. Can polydispersed measurements also be performed and coupled with for example results from SMPS-measurements? Please comment.

Page 9722, lines 9-11: please clarify if the B2S-method is for size-resolved measurements or not.

Page 9730, Figure 6 (b) and (c): Including error bars of the calibration curve and measurement results would add important information and credibility to the figures. Is the measurement point of tungsten oxides (WO) independent from the calibration?

### Technical corrections

Page 9714, line 11: change "is" to "may ... be" (or similar) in the sentence: "Model simulations show that the B2S approach **may** also **be** applicable for measuring CCN activation of..."

page 9714, line 2: change "budge" to "budget"

page 9715, line 20: change "the" to "a", i.e. "...a fast determination of  $\kappa$ ,..."

page 9716, line 18: add "an infinite number of" inside the brackets, i.e. "(because it corresponds to an infinite number of values of  $S_{aerosol}$ )"

Page 9717, line16: change " $\sigma_{sol}$  is the surface tension of water" to " $\sigma_{sol}$  is approximated by the surface tension of water"

Page 9718, line 19: change "For aerosol particles of the same composition (...), its  $S_{aerosol}$  and  $\kappa$  values..." to "For aerosol particles of the same composition (...), **their**  $S_{aerosol}$  and  $\kappa$  values..."

Page 9719, lines 3-5: The statement indicates more than one background site, please add more references.

page 9719, lines 25-27: Please include some descriptive text concerning the probability density function of the  $\kappa$  distribution ( $\kappa$  -PDF, in Figure 5 (a)).

page 9720, lines 26-27: Is this adjustment of  $S_{min}$  the same as changing the aerosol-to-sheath ratio? Please clarify.

page 9721, line 13: add the figure character, "Figure 6 (a) ..."

page 9721, line 20: add the figure character, "Figure 6 (b) and (c)..."

Page 9722, line 6: change “can” to “may”, i.e. “It may also be applicable...”

Page 9722, lines 13-14: change “...are especially well suited...” to “...may be well suited...” or similar. Due to the fact that no long-term measurements have been performed.

page 9729, Figure 5 (a) caption: include “( $\kappa$  –PDF)” in the sentence “The shaded isolines describe the probability density function of a two-mode  $\kappa$  distribution.” And add the reference (Rose et al., 2011) of the figure.

page 9729, Figure 5 (b) caption: emphasize that these are modelled results and not retrieved from measurements.

Supplement, Figure S1 caption: Are the circles pure water droplets? Please clarify. This figure is exactly the same (including figure caption) as Figure 2 in Wang et al. (2015).