Reply to Reviewer #2

We greatly appreciate all of the comments, which have improved the paper. Our point-by-point responses are detailed below.

RC – Review Comments; AC – Authors's Responses

Specific Comments:

RC: (1) On pg. 5907, line 20 is written: "The ambient temperature was assumed to be 15 C for rain cases and −10 C for snow cases and the ambient pressure was assumed to be 1013.5 hPa. How these assumptions impact on the new parameterizations? I suggest to the authors to add these results in the MS.

AR: We have conducted sensitivity tests using different temperature and pressure values to address this comment. Temperature values of 5^oC and 30^oC for the rain cases and -5^oC and -30^oC for the snow cases and an ambient pressure value of 900 hPa for both the rain and snow cases were used in the sensitivity tests. The differences caused by using different ambient temperature and pressure values are generally within 10% of the previously reported results for all particle sizes for both rain and snow scavenging; the only exception is for rain scavenging of particles of sizes 0.1-2.0 μm, for which the bias can be up to 30%. We have presented these results in a new figure, Figure 8, and have added a summary of the results of these sensitivity tests and related discussions in the revised paper to a new section, Section 4.3.

RC: (2) On pg 5919, line 5 is stated that "The new parameterization . . . is more realistic than the majority of theoretical _(d) formulas". In order to support that I suggest to the authors to add a comparison with other parameterizations for both rain and snow in the Sect. 3.1 and 3.2.

AR: The development of this new parameterization is based on results from our three previous studies (Wang et al., 2010, 2011; Zhang et al., 2013), in which we conducted detailed comparisons of existing theoretical formulas with available field data and empirical formulas. A major conclusion and recommendation from our previous studies is that, as already stated in the Introduction of this paper, the upper range of available theoretical values should be used in chemical transport models. That is why we chose to use the 90th percentile of values from an ensemble data set calculated based on most existing theoretical formulas as the basis for developing the new scheme. The comparison of this new scheme with existing schemes and field data would be similar to the comparisons already presented in Wang et al. (2010) and Zhang et al. (2013), and we chose not to repeat what was already presented previously.

RC: (3) pg. 5902: Since "empirical" refers to something relying on or derived from observation or experiment, I suggest to the authors to change the title in "Theoretical development of new parameterizations for below-cloud scavenging..."

AR: Formulas generated from the fitting of data are usually called empirical formulas. The data themselves can be field-measured data or theoretically-produced data. The theoretical formulations for scavenging coefficient Λ have a semi-empirical aspect because the expressions for some product terms (e.g., terminal velocity) are based on empirical fits to measurements. In this study, the ensemble data set of scavenging coefficient values was first generated from theoretical (or semi-empirical) formulas and was then fitted to new formulas. Moreover, some of the choices in the calculation methodology such as the decision to consider 90^{th}-percentile values were based on consideration of measurements as well as theoretical values. We thus think it is appropriate to describe the new formulas as "semi-empirical" since they are neither purely theoretical nor purely empirical.

RC: (4) pg. 5904, line 10: The statement "the only exception is one controlled outdoor field experiment that obtained rain to a similar order of magnitude to the theoretical values." has to be supported by the reference.

AR: The reference has been added in the revised paper.

RC: (5) pg. 5906, line5: "component parameters" are not appropriate terms. I suggest to use other terms all over the MS.

AR: We have changed the term "component parameters", which was used to refer to the factors of the integrand product in Equation (2), to "product terms" throughout the text.

RC: (6) pg. 5907, line 5:"a number of size bins or sections": the term "sections" is not usually used in aerosol microphysics, I suggest to be omitted.

AR: We believe the reviewer is referring to line 13, not line 5, of page 5907. The term "section" refers to one major modelling technique used in regional aerosol models to represent the continuous aerosol particle size distribution (i.e., a sectional representation). This terminology will be very familiar to AQ modellers even if it is not familiar to aerosol microphysicists. For example, here are a few references to papers that employ this term:

Jacobson, M.Z., 1997: Development and application of a new air pollution modeling system. Part II: Aerosol module structure and design. *Atmos. Environ.*, **31**, 131-144.

Meng, Z., D. Dabdub and J.H. Seinfeld, 1998: Size-resolved and chemically resolved model of atmospheric aerosol dynamics. *J. Geophys. Res.*, **103**, 3419-3435.

Seigneur, C., A.B. Hudischewskyj, J.H. Seinfeld, K.T. Whitby, E.R. Whitby, J.R. Brock and H.M. Barnes, 1986: Simulation of aerosol dynamics: a comparative review of mathematical models. *Aerosol Sci. Tech.*, **5**, 205-222.
Wexler, A.S., F.W. Lurmann and J.H. Seinfeld, 1994. Modelling urban and regional aerosols − I. Model development. *Atmos. Environ.*, **28**, 531-546.

We thus prefer to keep this term in the manuscript.

RC: (7) Fig. 1a and b: The caption should include what means red, black and yellow curves.

AR: The caption has been modified as recommended.