

Interactive comment on “A parameterization of size resolved below cloud scavenging of aerosols by rain” by J. S. Henzing et al.

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Referee #2

General comments The referee missed the parameters that are necessary to reproduce the results. We made the coefficients available via www.knmi.nl/~velthove/wet_deposition. We did not include a table with a selection of the coefficients in the paper. The reason for this is that we cannot include a huge table in the paper and using a smaller selection of aerosol radii than the selection provided will lead to unacceptable errors in the finally used integral scavenging coefficient (Eq.12).

Referee finds essential an evaluation of TM4 sea salt model against measurements. We have now included a comparison of model simulated sea salt with observations in

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section 4.1 paragraph 4. We also included new figures (Fig 5a-h) and a table containing the measurement locations (Tab. 1)

specific comments

1) We included references to recent works done on the below-cloud scavenging and we included references that introduce the process itself. Included new references: Andronache (2004), Zhang et al. (2004), Stier et al, 2005, Tost et al. (2006), and Mircea et al. (2000). 2) The referee is completely right. We have put a table containing the coefficients at the web (see also general comments). 3) We have compared the simulated sea salt concentrations with observations (see also general comments). 4) We included the original formula from Gong (2003b) as suggested. We decided not to report the formula of dry sea salt source function (indeed: $dF/dR_{dry} = dF/dR_{wet} \cdot dR_{wet}/dR_{dry}$) as the algebra involved is simple but the result is lengthy. 5) In section 2.1.3 last paragraph we define the scavenging coefficient beta that is also used in equation 4. beta-i is the scavenging coefficient that is valid for region i, Regions i=1-3, represent respectively the region inside precipitating clouds, the region below precipitating clouds, and cloud free regions. E.g. beta-3 is thus the scavenging coefficient in cloud free region s: beta-3=0. At the moment we define DELTA-tno-mix = N.DELTA-t, N is just a number. Not much later it becomes clear that choosing N fixes the number of calls, n, of the removal scheme since the last mixing instant, and thus N defines the time that air masses are not mixed throughout the grid cells. We have modified the text to make this clear for the reader. We have performed a few runs to get an idea of the sensitivity of the model response to the choice of six hour interval for the no mixing time scale and found that the difference between the old scheme (continuous mixing) and either 3 or 6 hrs no-mixing times was much larger than the differences in simulated aerosol mass mixing ratios obtained from runs with 3 and 6 hrs no-mixing. Choosing 3 or 6 is indeed rather arbitrary. Choosing 6hrs is then the most convenient. Longer no-mixing timescales may not be realistic; moreover new meteorological data is available and should be used.

The referee asks: "What is the consequence of assuming all aerosol particles acting as condensation nuclei, instead of having an activation radius?" Activation processes (nucleation scavenging) scavenge most aerosol mass within the cloud layer since a large fraction of the aerosol mass is associated with large aerosols which can be quickly activated into cloud droplets. Impaction scavenging inside the cloud layer may remove little aerosol mass but effectively removes the smallest aerosol particles in the early stage of a developing cloud (mainly by Brownian impaction) By the time the cloud becomes precipitating larger particles are also scavenged by inertial impaction. The speed of fall is then still small and thus even "Greenfield gap"-particles may be scavenged. According to Zhang et al., (Atmos. Environ., 38, 2004) total in-cloud scavenging in warm stratiform clouds removes more than 70% of aerosols in number and more than 90% in mass. For mixed phase clouds and ice clouds the in cloud scavenging is less effective due to the growth of ice crystals at the expense of water droplets as a result of the Bergeron-Findeisen process (Henning et al., Geophys. Res. Lett., 31, 2004). Henning et al. (2004) investigated aerosol partitioning between cloud and interstitial phases in natural, mid-latitude, mixed phase clouds using in situ measurements. Based on the fact that their observed fraction of interstitial aerosol is rather insensitive to particle size, we used their numbers to estimate the amount of aerosol mass that remains interstitial, and that is therefore not removed from our model atmosphere (Henzing, 2006, chapter 5, <http://alexandria.tue.nl/extra2/200610067.pdf>). The fraction of aerosol particle mass that is not incorporated in cloud droplets varies from 0.54 in warm clouds to 0.08 in cold clouds with temperatures below -15°C. We did not use these values in this paper but if so it would make the relative importance of below-cloud scavenging even larger. We feel that including a discussion on interstitial aerosol in this paper would divert the reader's attention and moreover it would not change our conclusion that below-cloud scavenging is important and should be accounted for in global models. The rest of the paragraph..is not clear. We have improved the text.

6) The referee remarks that super-micron particles will probably dry deposit not far away from the sources. We agree, and included the remark in Section 4.2 paragr. 2.

7) Here we did not want to discuss which function is better for representing precipitation: a gamma distribution or an exponential fit. What we wanted to stress is that the gamma distribution we have chosen is fitted to measured data representative for global average continues rainfall. This specific gamma distribution with fit parameters given in Eq. (3a) and (3b) may not be appropriate for individual precipitating systems, despite the fact that a gamma distribution may, or may not, result in a better representation of that precipitating system than an exponential fit. In Paragr. 5.1 we give other distributions in order to give the reader an indication of this sensitivity. One of the alternative droplet distributions used could have been a gamma distribution. The text is changed for clarification. Referee #2 is rightly confused. Indeed we used the De Wolf gamma distribution. Compared to the other exponential fits, this distribution contains less very small rain droplets that are very effective in collecting aerosol particles. According to the referee the distribution that is closest to our distribution is the Marshall and Palmer distribution. This is true for the larger rain drops. The gain of the De Wolf distribution is however that it better predicts the small droplet part of the spectrum. That is why the results of the Joss THUNDERSTORM, which also contained fewer small droplets, resemble our results best. In the paper we interchanged the words DRIZZLE and THUNDERSTORM. We apologize for this mistake and have corrected the text. We explained the sentence: "The central plus....distributions" as requested by the referee.

8) Indeed, aerosol dry mass plus water. The text has been made clearer. 9) In Paragr. 5.3, we mention that evaporation is handled implicitly. Calculated precipitation formation rates are used for the vertical structure of precipitation. The total amount is scaled (back) to the surface precipitation archived by ECMWF. The difference between online calculated and offline stored precipitation may partly be explained by evaporation below the cloud. In our model this evaporation is neglected because information about this is not available from ECMWF. See also under 5) and section in-cloud scavenging in section 3.2.1 in the paper. 10) We now included a comparison to observations. See also general comments. 11) The figure caption has been modified as suggested.

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