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Interactive comment on "Subgrid-scale variability of clear-sky relative humidity and forcing by aerosol-radiation interactions in an atmosphere model" *by* Paul Petersik et al.

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Response to Steven Ghan

We thank the reviewer for his constructive comments and for his thorough review. The reviewer comments are in plain font, the authors responses in *Italics*.

General comments

This study introduces stochastic sampling of the PDF of humidity to examine subgrid humidification effects on aerosol radiative forcing. Although this represents an advance over previous estimates of aerosol radiative forcing, important details that

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Discussion paper

could substantially influence the results are missing in the description of the treatment. I cannot recommend publication until these details are provided, and only then if the clarified treatment does not substantially bias the results.

The reviewers concerns are to our understanding mostly based on our insufficient description of the aerosol-module HAM2. Therefore, we include a new subsection, "2.1 The aerosol module HAM2" into our methods that briefly summarizes the properties of HAM2.

1. Page 3, lines 23-28. How is the hygroscopicity of each mode determined from the hygroscopicity of each component in the modes?

In ECHAM6-HAM2 the hygroscopicity of internally-mixed aerosols is determined by calculating the volume weighted sum of the κ-values form each soluble compound (see Zhang et al. (2012) section 4.1.3). This is now better explained in the revised paper.

2. Section 2.3 a. How is humidification effect on extinction treated? Extinction is not a simple function of particle radius. See, for example, the method of Ghan and Zaveri (2007). The treatment must be described and justified.

Aerosol radiative properties are calculated using Mie theory. The model uses volume-averaging for each of the seven aerosol modes to calculate the refractive indices where aerosol water is included using the ambient relative humidity. The effective complex radiative indices and the Mie size parameter is then used for the aerosol radiative properties, namely extinction cross section, single scattering albedo, and asymmetry parameter in the radiation scheme (see Zhang et al., 2012, section 2.6).

We thank Dr Ghan for pointing us to this reference, which we now include in the discussion in the revised paper.

b. Does the model treat absorption enhancement by humidification? Some people (Jacobson) think this is quite important.

For the version 2 of the aerosol module HAM the refractive indices for black carbon were updated to reduce the the negative biased aerosol absorption enhancement (Stier et al., 2007). In Stier et al. (2007) it is argued that on a global scale the absorption enhancement of BC due to mixing with hydrophilic aerosols is compensated by the lower life time of and abundance of BC. They base this argument on the study by Stier et al. (2006) where they find that reduced lifetime of BC due to internal mixing actually overbalances the absorption enhancement effect on a global scale such that they observe a decrease in global annual mean clear-sky atmospheric absorption of 0.2 W m^{-2}. Furthermore, the hypothesis of Jacobson (2012) is very controversial and not supported by most other studies (e.g. Twohy et al., 1989; Chýlek et al., 1996; Liu et al., 2002).

c. Why use the clear-sky value? This biases the estimate of ERFari. Why not include a diagnostic no-aerosol radiation calculation and diagnose ERFari following Ghan (2013)?

We followed the advice of the referee. We now present our results in terms of a radiative forcing due to aerosol-radiation interactions (RFari) that is calculated as suggested by Ghan (2013). As one would expect, RFari changes less (from -0.15 to -0.19 W m^{-2}, ∼31%) due to the masking effect of clouds than ERFari$_{\mathrm{cls}}$ (from -0.29 to -0.45 W m^{-2}, ∼57%) in response to the implementation of our parameterization. However, we still

observe a clear signal that the implementation of our parameterization enhances the cooling by the direct aerosol effect.

3. Page 7, last paragraph. Your argument about scattering vs absorption would be stronger if you compare the impact on AOD with the impact on AAOD. It is likely that the sensitivity of ERFari is biased by your treatment of humidification effects on absorption and by neglecting contributions from cloudy sky.

We have included two variables into the Table 1, namely AAOD and AAOD by black carbon. We see a positive change in AAOD +0.12 · 10^{-3} ($\sim$ 4.7%). However, AOD changed in absolute values by nearly two orders of magnitude more, namely + 9.0 · 10^{-3} ($\sim$ 7.8%).

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