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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impact of mineral dust on cloud formation in a Saharan outflow region" *by* L. Smoydzin et al.

Anonymous Referee #1

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In this manuscript, Smoydzin et al. use the fully coupled chemistry version of the Weather Research and Forecasting model (WRF-chem) to investigate the influence of mineral dust on cloud formation during two cases where dust plumes originated from the Sahara Desert crossed the Eastern Mediterranean and interacted with clouds. The paper is, in general, well written, and contains relevant scientific information that will add to the current level of understanding of the impact of mineral dust on cloud formation and precipitation. I recommend the paper for final publication, after some issues are addressed.

General Comment:

1. This paper focuses on the impact of mineral dust on cloud formation. Given that, a more sophisticated cloud droplet activation parameterization (than one used) is needed

to represent these interactions. Kumar et al (2009a;2011a) suggested that adsorption activation theory (AT) better represents fresh dust-water interactions than Köhler theory (KT), as the dependence of critical supersaturation with particle dry diameter is closer to observations. The CCN activity of wet processed dust though, is more consistent with KT at small particle sizes and with AT at larger particles. To address this gap, the unified CCN activity framework can be used, developed by Kumar et al. (2011b), that accounts for concurrent effects of solute and adsorption to describe the CCN activity of aged or hygroscopic dusts. Karydis et al. (2011) used this framework to provide a first assessment of the contribution of insoluble dust to global CCN and cloud droplet number concentration (CDNC). Bangert et al. (2011), using this framework, also investigated the impact of mineral dust particles on clouds, radiation and atmospheric state during a strong Saharan dust event over Europe in May 2008. Overall, considering the hydrophilicity from adsorption and hygroscopicity from solute is required to comprehensively capture the dust-warm cloud interactions. I suggest to add a similar discussion in the manuscript and also comment on the simplification of i) using the KT for describing CCN activity of particles that contain mineral dust and ii) assuming that the bulk aerosol hygroscopicity is the mean value over all bulk aerosol components.

Specific Comments:

1. Page 32364 line 4: Replace "days" with "cases. The second episode lasts for two days and not one.

2. Page 32364 line 23: The start of the sentence is confusing. The authors may need to rephrase, i.e. "In addition aged, chemically altered dust particles can act…"

3. Page 32366 line 5-6: Mineral dust is hydrophilic and not hydrophobic as mentioned in the text (Sorjamaa and Laaksonen, 2007;Gustafsson et al., 2005;Hatch et al., 2008;Vlasenko et al., 2005). In addition, Kumar et al. (2009a, 2011a) suggest that even fresh unprocessed mineral dust can also affect warm clouds by acting as CCN. Please comment on these as well.

4. Page 32366 line 20-21: Other studies though suggest that dust particles with a soluble coating can also maintain their activity as IN (Levin et al., 2005). Please add this (or similar) reference too.

5. Page 32366 line 24-26: Tropical Atlantic Ocean is also often influenced from dust particles originating from Northern and Central Africa (Karyampudi and Carlson, 1988;Karyampudi et al., 1999;Chiapello et al., 2005;Kallos et al., 2006)

6. Page 32367 line 21: Replace "parametrisation" with "parameterization". This error is repeated several times in the manuscript.

7. Page 32368 line 6: Which is the size range of the four largest size classes? Several studies have reported mineral dust size distributions including modes with median diameter as low as 160 nm (D'Almeida, 1987;Chou et al., 2008).

8. Page 32368 line 8: The most appropriate theory for describing the CCN activity of mineral dust is the FHH-adsorption theory (Kumar et al., 2009b), which uses the AFHH and BFHH parameter to express its hygroscopicity. In case of using the Köhler theory though, the use of a hygroscopicity parameter between 0.005 and 0.05 for freshly emitted mineral dust seems more realistic according to Kumar et al. (2011a; Figure 2).

9. Page 32368 line 26: The 12h case is neither in Table 1 nor discussed later in the manuscript.

10. Page 32369 line 15: Replace "case study days" with "case studies"

11. Page 32370 line 1: Replace "summer/autumn" with "autumn"

12. Page 32370 line 11: Please refer the number of the figure in the supplement. This omission is repeated several times in the manuscript.

13. Page 32371 line 23: Please use either "spacial" or "spatial" in the entire manuscript.

14. Page 32372 line 9: Please include a brief description of the "NOfeedb" scenario in

"model setup" section.

15. Page 32375 line 16: Replace "range of" with "in the range of"

16. Page 32375 line 28: It is not apparent from figure 4 that precipitation is initiated earlier when dust is present. The authors should explain this more. They can i.e. place an arrow or a box in the figure to help the reader focus on the area that this shift is more apparent.

17. Page 32376 line 4-6: Some readers may confuse and refer to Figure 4 for this sentence. I suggest either to include a figure with the 24h accumulated precipitation (it may be interested) or to add "(not shown)" at the end of the sentence.

18. Page 32376 line 12: Replace "summer" with "autumn"

19. Page 32376 line 24-27: As mentioned in the general comment, other weaknesses of the model setup are i) the use of KT for describing CCN activity of particles that contain mineral dust and ii) the assumption that the bulk aerosol hygroscopicity is the mean value over all bulk aerosol components. Please also comment on them.

20. Page 32377 line 27: Replace "case study days" with "case studies"

21. Figures: Please improve the quality of the figures. For instance, the numbers and letters on the axes are not very clear.

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