24 February 2013
Response to Referee 2
"Mineral Dust Indirect Effects and Cloud Radiative Feedbacks of a Simulated Idealized Nocturnal Squall Line"
Robert B. Seigel, Susan C. van den Heever, and Stephen M. Saleeby

General Response to Referees
The authors thank the two anonymous referees for reviewing and commenting on this manuscript. We appreciate your thoughtful comments and suggestions, as they have helped to improve the quality of this manuscript. We are also pleased that both reviewers have found merit in this work. In addition to many specific changes that have been made, the following more major modifications have been made to the revised manuscript:

1) The title has been changed to avoid confusion regarding aerosol direct effects. It is now "Mineral Dust Indirect Effects and Cloud Radiative Feedbacks of a Simulated Idealized Nocturnal Squall Line".
2) More details and information are included regarding the microphysics and aerosol schemes used in this study and in RAMS. We have included a table that summarizes some pertinent microphysical and aerosol information, along with many additions to the Methods section.
3) Additional text has been added to the Summary section that describes the exclusion of aerosol direct effects in this study, and the need to investigate them in future studies. Please see the specific responses for further details regarding the exclusion of direct effects.
4) The references to the various microphysical quantities discussed throughout the Results section have been changed to make the manuscript easier to follow. The only words in uppercase are the factors, while the microphysical quantities are now simple shorthand references.

Please see the responses to your specific comments below.

Specific Response to Referee #2: Author comments in bold

Anonymous Referee #2

Review of "Assessing the mineral dust indirect effects and radiation impacts on a simulated idealized nocturnal squall line" by R. B. Seigel et al.

General Comments

The authors used the RAMS as a cloud-resolving model to investigate the individual effects of mineral dust on a simulated idealized nocturnal squall line through (1) radiation, (2) cloud microphysics, and (3) the synergistic effects between (1) and (2). Factor separation is used on four simulations. Analysis shows that dust-radiation interaction increases precipitation and enhances the squall line, while dust-cloud interaction decreases precipitation and weakens the squall line. The synergistic effect is small.

Dust is the most abundant aerosol species in the atmosphere and has significant impact on regional and global climate. I find this topic about dust impact on squall line is interesting and important, although it is in an idealized case. However, I don't understand why the authors want to separate the dust-cloud interaction from the dust-radiation interaction. This study designed experiments to exclude dust radiative effect. The dust impact on radiation and its impact on cloud are normally fully coupled. It is necessary to include both of them, unless there is specific reason to exclude it. I didn't see any technical difficulties in this study to include dust-radiation interaction. I would suggest the authors extending their analysis to dust-cloud-radiation interaction and change the title to something like "assessing the impact of mineral dust on a simulated idealized nocturnal squall line". The excluding of analysis of dust impact on radiation will significantly reduce the values of this paper, although the idealized squall line is nighttime. I think the topic is suitable for publication in ACP after including the dust- radiation interaction and addressing some specific comments below.

Thank you for these comments. The authors recognize and fully agree with you in that the inclusion of the dust-radiation interactions in this study would be a next great step in understanding total aerosol impacts on organized deep convection. The inclusion of the direct effect would have an impact on the radiative budget of the pre-squall line environment, potentially leading to changes in thermodynamic forcing of the squall line. A brief discussion regarding our decision for deliberately neglecting the direct effect has been placed in the Introduction and Summary sections.

While this is an interesting and important feedback to better understand the interactions of aerosols and deep convection, we feel that the inclusion of the direct effect would be too much analysis for this manuscript. To include the direct effect in the factor separation analysis, three additional simulations (two of which being synergistic) would need to be run, analyzed and discussed. The extra analysis and discussion would force a reduction of the current analysis, which we feel is important to keep in tact due to its complexity. While the direct effect is relatively well-known and can be directly simulated within all scales of models (e.g. GCM, regional, LES), aerosol indirect effects are far more complex and more difficult to simulate within models utilizing convective parameterizations. In this study, we deliberately chose to isolate the indirect effects to aid our understanding and interpretation of aerosol-cloud interactions. By isolating the indirect effects and improving our understanding of these processes, we hope to assist the science community in furthering modeling capabilities, especially those working on mesoscale organization in GCMs.

The direct effects are currently being analyzed and will be submitted for publication elsewhere.

Specific Comments

1. This study conducts one simulation for a 7-h case without any ensemble simulations. When authors subtract the result of one simulation from that of another one, how can the statistic significance be tested? The difference between two sensitivity simulations, sometimes, comes from the numerical noise. I would like to see the statistical significance for all the signals when draw the conclusion.

You raise an interesting point. This study is indeed an idealized approach to obtain valuable information on process modification resulting from variations in aerosol concentrations. From this one squall line scenario (four simulations), how can significance be tested? One approach, as you mention, would be to run many different idealized squall line simulations and perform significance testing on the ensemble of solutions. However, this would be VERY expensive. The detailed microphysics that is included in RAMS and necessary for this kind of analysis is very memory, time and storage intensive. Running the required number of simulations to gain significance for each of the factors would not be possible with today's technology.

Another option is to use a case study to evaluate the model's ability to reproduce results, rather than "numerical noise". However, we do not know of any such dataset that includes in situ measurements of a squall line encountering a dusty environment. That would enable investigation of dust impacts on squall lines.

Because of the difficulties described above, we feel that our approach is the best option. By averaging the output temporally, we significantly reduce the "numerical noise" that the reviewer is concerned about. If two instantaneous times are compared, the dominant processes involved with aerosol-cloud interactions may vary. However, when averaging over 4 hours (as we did in this study) the dominant processes become more apparent and physically sound.

2. More description about dust properties including dust emission, size distribution, and optical properties. Aerosols are internal or external mixed?

We have included more information regarding the microphysics and aerosol properties. A table, along with in-line text has been added to the revised manuscript. We have also included a draft of the accepted manuscript, Saleeby and van den Heever (2013), for your reference. The aerosols that we represent in our model are externally mixed.

3. The sensitivity simulation without dust-cloud interaction will affect the wet deposition as the authors mentioned. The effect should be examined. For example, are the dust concentrations significantly different between the standard simulation and the one without dust-cloud interaction?

Thank you for this question. The differences are indeed significant. When dust is not allowed to nucleate as CCN or IN, the only wet mechanism by which dust is

removed is through collisions either within the cloud or by the precipitation shaft. This removal efficiency is small in comparison to that from nucleation. When dust is allowed to nucleate, nearly all of the dust is removed by the updraft. This is because the updraft of the squall line is so strong (~ 30 m/s at times). Large supersatrations are generated and all dust particles are nucleated into cloud or drizzle drops. The wet deposition rates differ by orders of magnitude between these two simulations. Discussion in this regard has been added to the Results section of the manuscript.