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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Spatial distributions and seasonal cycles of aerosol climate effects in India seen in global climate-aerosol model" *by* S. V. Henriksson et al.

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General Comments

This paper aims at assessing the aerosol-rainfall-climate connections over India due to the direct (effects) and indirect effects (DE & IE) of aerosols on the vertical structure of the radiative heating, temperature profiles, and precipitation yields. The investigation relies on a suite of ECHAM5-HAM model simulations comprising of nine runs in which the DE and IE of aerosols are turned on and off with and without the GAINS inventory of anthropogenic emissions. The SSTs are prescribed and kept identical in all the

simulations except for two (one with only DE and one with both DE and IE turned on) in which SST modification entail SST-reductions (of 0.5K) as a proxy for the solar diming by aerosols over the nearby Oceans. The data are used to evaluate two recently identified aerosol impacts: i) the Elevated Heat Pump (EHP) effect enunciated by Lau and Kim (2010) and ii) the Solar Diming effect (SDM) identified by Ramanathan et al. (2001, 2007) vis-a-vis the influence of assumed SST anomalies caused by aerosols. The authors examine the rainfall changes in the 1) pre-monsoon or MAM, 2) summer monsoon or JJA, 3) monsoon withdrawal and early winter or SON, seasons. The take home message of the research is that both EHP and SDM are active and counter each other. Whereas EHP causes rainfall invigoration, SDM forces rainfall reduction, and in the balance SDM effect outweighs the EHP effect on rainfall. The authors do not discuss as to how dependant are the findings on the strengths or weaknesses of the particular model.

ECHAM5-HAM model is a world class climate model and GAINS data provides a comprehensive aerosol emission inventory. Moreover, the model's current version has been shown to produce reasonable features of aerosol-cloud-radiation forcing and hence I recognize how the simulations can be expected to provide worthwhile results. Nevertheless, the model resolution is coarse, particularly for capturing the EHP effect over Himalayan orography. Also, it may not simulate realistic aerosol number and mass density gradients to accurately develop and modulate the horizontal structures of atmospheric stability which, in turn, impacts dry and moist convection and hence the monsoon circulation over India. It is well known that model-based inferences contain a mix of GCM's biases and atmosphere's reality. Moreover, models with aerosol physics also need good aerosol input that comprise of aerosol particle size, chemical composition, solubility, CCN activation and IN formation properties; together with a well validated parameterization of precipitation microphysics and model's ability to generate realistic juxtapositions of aerosols and clouds in the vertical. It is a tall order and one sees the need to validate the results against observations. I therefore suggest some additional diagnostics to assess the fidelity of the simulated monsoon circulation over

India. These are likely to provide a stronger scientific base to the inferences outlined in the paper! Indeed, the suggested diagnostics also have a better potential for validation against real observations. Hence I urge the authors to give them due consideration.

Specific Suggestions and Recommendations

As to the usefulness of modeling based inferences, readers often like to know how representative are the GCM simulations over India? Do the model simulations have the key characteristics of the Indian circulation that comprise of reasonable: i) high pressure ridge in the north in MAM; ii) orientation and intensity of monsoon trough in JJA; iii) vertical temperature structure with its consequences on Intraseasonal Oscillations (ISO) with the intensity and frequency of convective events embedded into ISO; as well as iv) the onset and withdrawal of monsoon circulation and rainfall. Indeed, westerly disturbances of the winter season are also an integral part of model's characteristic, but those are not evoked in this study; so I would not bother the authors with them. If the assessments outlined above have been published already, the authors may reference them, but a reasonable discussion of model's strengths and/or deficiencies and how those might impact the outcome of the present study would be very helpful. Indeed, if the model simulates reasonably well the key circulation features over India, the next interesting question is "how do aerosols affect these features? This will give ACP readers an invaluable insight into the intrinsic value of the aerosol effects on the Indian monsoons. On the other hand, if the monsoon characteristics of the baseline model have significant biases, the reader needs to know about them. Clearly, such diagnostic are vital for meteorology associated with the new findings. After these questions have been addressed and the paper is revised to reflect the model's ability to predict and modulate the monsoon circulation over the Indian subcontinent, the paper would be suitable for publication. However, aerosol-SST connections remain a wild card because proxy derived SST anomalies are arbitrary! A better way would be to compute SST changes consistently with a slab ocean model, but I also realize, it may be asking too much to include it in the current investigation.

In closing, I like to state, the authors have made a laudable beginning in making an interesting series of runs with the ECHAM5 model using the best available aerosol inventories and finally ending up with the EHP and SDM comparisons. This qualifies the work for dissemination in the published literature; however, the analysis is weak on probing into changes in the monsoon circulation; the suggested diagnostics are vital for enlightening the reader about the intrinsic value of the new findings. I expect the authors to use the available data (to the extent possible) and show the success of the model in simulating the key features of the circulation over India. They may like to use the analyzed circulation fields (from somewhere ECMWF or NCEP) for model evaluation. Once these diagnostics are included, the assessment of circulation meteorology will become adequate. I would not seek to review the revised paper because my comments and authors responses will appear together and will reflect naturally on the value of the current results.

Technical Comments

Herein, I make some editorial comments. These are for the benefit of the authors; these may not be web posted.

There are some instances of unclear/awkward English sentences. I am sure, Journal's technical editors would provide professional help for improving them, but I presume it will be better if authors can perform their own due diligence! I have pointed out the obvious ones. I couldn't help more because I am not very good at nit-picking; in fact, I too have to rely on professional editors, which conveys, I am also not good with them.

1. Page 3, line 25: Spell out Sect. to Section.
2. Page 4, line 14: Vague statement "where correspondence with MODIS results was not that good". Reword "that good". Also, delete stating both inferences in the follow-on extension of the sentence.
3. Page 4, line 16: Watch out for tenses; past and present tenses are mixed up

here.

4. Comment: Why are you discussing the aerosol inventories with such extensive details of the history behind them? According to your references, GAINS model was written up in 2011. Why not outline briefly the GAINS system (like you do for the ECHAM5 model) and avoid side tracking the reader with details of aerosol inventories because you do not use them subsequently for explaining science of the climate change.

5. Page 5, line 05: Delete “to us” in “feasible to us.”

6. Page 5, line 05: Change “idea” to “estimate.”

7. Page 5, line 20: “as well as waste” I don’t understand what you mean; change “waste” to “waste products” and spell out the products! Have I misunderstood your intent?

8. Page 5, line 25: Modify “national experts including. . . .” It is a vague reference; specify individuals or groups by proper reference(s).

9. Page 5, line 29: Reference needed “23 Indian administrative regions”. This is not common knowledge. Use a reference.

10. Page 6: there is too much detail here; I suggest: curtail some of the inconsequential excursions.

11. Page 7, line 24: “All simulations were run for the years 2005–2010 the years are not that important.” It is okay in a speech, but not formal writing. State something like: “herein, specific years are inconsequential for because year 2005 aerosols are used in every year, but SSTs do vary”

12. Page 8, line 6: “interpolated to Mukteshwar with measurements” unclear statement!

13. Page 8, line 3: “raising confidence in the model results”? Do you mean “making simulations more realistic?” Confidence level is a statistical number!

14. Page 8, line 25: “is shown in Fig. 3 for the top of the atmosphere (TOA)” change to “are shown for the top of the atmosphere (TOA) in Fig. 3.” Avoid repeating Figure Captions in the text; instead key-in on the salient features of the figures.

15. Page 9, line 1-3: “The anthropogenic. . . only” Unclear sentence!

16. Page 9, line 9: Description of Figure 6 in the text is convoluted to understand without re-reading it a few times. Simplify and make it easier for the reader! Why not leave the Figure Captions out of the main body of the paper. That way you will write them only once and it would be easier on the reader too, who will be looking at the figure and its captions together. Instead use the text-space to discuss the key features in the figure.

17. Page 9, line 18: Reword “without and with” to “with and without.” How about: “The 2m air temperature anomalies are similar in Figure 7 and Figure 8. They are mostly negative except for MAM period over Northern India when the aerosol loading in MAM is high and the 2m-temperature anomalies are positive. . . . . ..”

18. Page 9, line 22-25: “A warming troposphere. . . Lau and Kim (2010)” This is an important result. It should be discussed *vis-a-vis* the EHP mechanisms with numbers for the key diagnostic and the anomalous circulation fields.

19. Arguments to resolve the controversy (Page 10) makes good sense because the outcome is based on a modeling investigation using a reasonable aerosol input data; nevertheless, the basis for SST modifications are not discussed. Effects of model biases on simulated results should be also be discussed here and pointed out in the conclusions.

20. Page 10, line 1-12: Description of rainfall anomaly reflects a “show and tell” mode. Discuss the associated circulation changes.

21. Page 11, on the subject of EHP versus dimming: The outcome will be affected by cloud height, cloud fractions and single scattering albedo that are often prescribed or empirically contrived. The models are often tuned to be reasonable but tuning could affect a subtle inference? Discuss it here.

22. Page 12, line 2: “high rainfall for a longer time during the year” Quantify; if possible, provide the time-scales!

23. Page 12, lines 6-7: The statement “Without anthropogenic emissions, the rainfall is decreased without cloud activation and not changed much with cloud activation included”. It is confusing; please revise

24. Page 12, line 9: “Yet, one more point we want to make that. . . ” is verbose. Simply state the point; use “moreover or indeed” if you like to emphasize the point.

25. Page 12, line 26: “One simulation was performed using the ERA-Interim reanalysis weather for nudging.” Are you describing the setup of the NUDGED simulation? In the end I sort of see what you mean, but it is better to make it easier for the reader.

26. **Respond to my Specific Suggestions and Recommendations.**

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 18031, 2013.