

Interactive comment on “The fate of Saharan dust across the Atlantic and implications for a Central American dust barrier” by E. Nowottnick et al.

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The fate of Saharan dust across the Atlantic and Implications for a Central American dust barrier

This is a solid paper looking at an important problem. It should be published with minor revisions.

Response to Reviewer #2

We appreciate the care and time of reviewer #2 in reading and commenting on our manuscript.

1. “Additionally, insoluble iron in dust aerosols can be converted into a soluble form

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via photochemistry and cloud processing (Hand et al., 2004; Kieber et al., 2003; Desbouefs et al., 2001; Zhu et al., 1997), which when deposited at the Earth’s surface can serve as a nutrient source for aquatic and terrestrial ecosystems (Mahowald et al., 2005; Jickells et al., 2005; Falkowski et al., 2003).” Some iron starts out soluble: see those papers.

We have noted that dust aerosols contain both insoluble and soluble forms of iron. The text now reads:

Chemically, dust aerosols are comprised of both soluble and insoluble forms of iron. While the iron in dust aerosols is primarily insoluble, photochemical and cloud processing can convert it into a soluble form [Hand et al., 2004; Kieber et al., 2003; Desbouefs et al., 2001; Zhu et al., 1997]. This has biogeochemical implications, as soluble iron in dust aerosols can serve as a nutrient source for aquatic and terrestrial ecosystems [Mahowald et al., 2005; Jickells et al., 2005; Falkowski et al., 2003].

2. 2nd paragraph of the introduction. Winckler et al., 2008 shows that there is an incorrect gradient in many of the gcm simulations of the dust deposition to the Pacific Ocean: too much north African dust is coming across. You can see this in the source apportionment studies of Luo et al., 2003; Tanaka and Chiba, 2005; Mahowald, 2007; North African dust is sneaking through in the tropics. Notice this includes reanalysis and gcm wind based models. Thus, the issue of how much dust gets through Central America is an important one.

We have added references to Winckler, Luo, Tanaka and Chiba, and Mahowald to indicate the significance of this issue to the reader. We have modified the text:

We find this barrier is also present in chemical transport model simulations of Saharan dust transport, though consistent with previous analysis of simulated dust transport [Mahowald, 2007; Tanaka and Chiba, 2005; Luo et al. 2003], our model simulates too much dust transport over the Pacific Ocean, and therefore does not reproduce the observed sharpness of the barrier. Winckler et al. [2008] suggested that simulated

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dust transport to the Pacific is the result of an incorrect gradient of dust removal in many global aerosol transport models. Our results support this by showing that the ability of our model to reproduce the observed barrier gradient is sensitive to the treatment of dust loss processes.

3. "To evaluate Saharan dust transport to the Caribbean and understand the Central American dust barrier we performed a baseline GEOS-5 replay simulation using the MERRA analyses": "replay": this is usually called hindcasting in the world of meteorology (although replay does sound more fun, like a video!).

"Replay" has a specific meaning in our context. Where a traditional (offline) CTM performs a hindcast by temporally interpolating reanalysis meteorological fields to intermediate time steps, in our model we replace the meteorological state with the reanalysis and perform a forecast to the next reanalysis state (so, every six hours). In this way we reproduce the functionality of CTM hindcast simulations but preserve the advantage of the offline system (consistent meteorology and transport). This terminology was also used in Colarco et al. 2010 (see reference in paper). We have modified the in Section 2.1 text as follows:

"Rather than formally running the data assimilation system, we replace the model's meteorological state with the state from a previous data assimilation run. This is functionally similar to hindcast simulations performed in offline chemical transport models (CTMs) in that meteorological analyses are used to drive the model for a specified period of time. The difference is that in offline CTMs the meteorological state is typically interpolated between the analysis time steps, whereas in GEOS-5 we are making a self-consistent forecast during this period."

4. 4.1 is really a methods section and should be put into the above methods section, not in the results. Separate out the results and keep them in 4.1: this will make the paper much better.

We have separated out the equations for the dust mass budget and for determining

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the rotational and divergent components of the dust flow and moved them into the discussion of our methods in Section 4.

5. "Our analysis of Eq. (2) uses monthly mean components that have been computed from instantaneous model output at every 3 h; thus, the fields examined include both the mean flow and the contribution from transient eddies." I hope you are doing this analysis on the 3 hourly instantaneous output and then plotting up the monthly means. If you are, then please clarify that by saying: "Our calculation of Eq. (2) use 3 hourly instantaneous model output to determine monthly mean dust mass fluxes; thus, the fields examined include both the mean flow and the contribution from transient eddies."

For this calculation, we used the 3-hourly instantaneous output to obtain the monthly means. We have included your wording to clarify how the calculation was made.

6. "The best agreement between our model and the observations was obtained when dust wet removal was treated as we treat the removal of hydrophilic aerosol species." This is completely consistent with the observations that dust readily attracts water when unprocessed Koretsky et al., 1999, and that dust readily acts as a CCN (Nenes et al., 2009? New articles from Thanos Nenes' group). I'm not sure where the idea came up that because dust is insoluble it does not readily attract water (except the Fan et al paper, and we did not need that to capture the correct Pacific trend in our model, so we know it was model dependent), but it's completely inconsistent with the literature or our understanding of minerals, and should be eliminated from the literature as much as possible. Your paper should help do that.

We have added references to these papers to support our finding that dust removal be treated as other hydrophilic aerosols. The text now reads:

The best agreement between our model and the observations was obtained when dust wet removal was treated as we treat the removal of hydrophilic aerosol species. This result is supported by observations of unprocessed dust aerosols attracting water [Ko-

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retsky et al., 1997] to readily serve as a cloud condensation nuclei (CCN) [Kumar et al., 2009]

7. "The implication of appealing to an increase in dust wet removal efficiency is that perhaps processing of dust during transport results in a more hydrophilic aerosol. Such an aerosol would likely be more bioavailable to oceanic organisms once it is eventually deposited." There is absolutely no need for atmospheric processing of dust for this to occur, as indicated above, and for North African dust coming across the north atlantic there probably really isn't time or sulfate: you can see this in the processing times of Hand et al., 2004. And wet deposition being more efficient for dust than previously thought has no implications for bioavailability, even if it required atmospheric processing, so please remove these two sentences in the conclusions and anywhere else they appear.

These sentences have been removed from the text.

8. Figures: I think figure 2 and the repeat (figure 14) are excellent ways to show what you are doing.

Thank you!

9. Figure 9 should clarify that these are the dust production and loss terms (figures should be stand alone), and indicate where in the text the calculations is derived.

We have separated the storage, $P - L$, and transport terms into individual figures and point to the appropriate equations in Section 4.

10. Figure 10 is my favorite. I like this way of looking at things, and it much more interesting than figure 11 or 12: I would prefer to see a horizontal plot of figure 10, with different colors represent different strengths of different processes across the whole north atlantic region.

We have replaced this figure with a spatial plot of the different strengths of the different processes over a broader region over the North Atlantic. This requires breaking the

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figure into two parts. The first figure shows ratio of dry removal to wet removal. This shows that wet removal become significant with distance from the source region. The second figure then shows the ratio of convective scavenging to large scale scavenging for each grid cell, thereby showing that convective scavenging is the most significant removal process over the Caribbean for our simulation.

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