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Atmospheric Chemistry and Physics Discussions

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

Overall, I recommend publications with "minor to moderate" revisions.

Response to Reviewer #1

We appreciate the care and time of reviewer #1 in reading and commenting on our manuscript.

1. Recently, I have become much more sensitive to papers which claim to "discover" some aerosol phenomenon which in fact has been well known in the community, but

is nevertheless new to the authors. I think the dust barrier is one such case and the authors should acknowledge that fact. Many of us in the dust community were aware of this feature, and in fact several proposals submitted to TC4 noted the dust barrier feature. Indeed, given the case studied in this paper was picked speciïňĄcally because it coincided with the TC4 tropical convection campaign should be a pretty good a-priori indicator as to which way the hypotheses would go down. However the authors have a solid point that this important feature has never been adequately studied and the rationale should be framed in that way.

We have modified the introduction to change the tone of our investigation of the dust barrier, but note that to our knowledge, we are the first to investigate its cause. The text has been modified as follows:

While numerous studies have focused on the broader patterns of dust transport and deposition into the Caribbean [Kaufman et al., 2005; Mahowald et al., 1999, Tegen and Fung, 1995; Duce et al., 1991], we are not aware of any studies which have focused on the mechanisms for the observed barrier to dust transport into the Pacific and its representation in global dust transport models. We are uncertain as to the relative roles of dust removal and transport processes in establishing and maintaining this barrier. Furthermore, while dust removal processes such as precipitation scavenging certainly are important, there are insufficient data to fully constrain the representation of these processes in aerosol transport models. Perhaps better constrained are dynamical features, insofar as they are well represented in meteorological analyses, and we may ascertain the relative importance of meteorology in tracer transport studies.

2. Along these same lines, the paper is framed so much like a case study it excludes the solid climatological grade veriïňĄcation which they perform. The paper perhaps would be better served in a format such a a) Look there is this interesting dust barrier feature that nobody has fully explored. B) It is important for understanding aerosol lifecycle, with both important geochemical cycling and air quality implications. C) This feature has been persistent and this is its overall phenomenology (it took me 20 min-

ACPD
11, C6544–C6550, 2011

utes on GIOVANNI to show that MODIS, MISR and OMI show this exact feature every summer June-August for the last 10 years, another 30 minutes on the NCAR reanalysis site to reasonably accept hypothesis 1-scavenging. If as a reviewer I can take this trouble, so can the authors) D) During TC4 we have observations, it suggest hypothesis 1-scavenging too e) This partially veriïňĄes in the model, but the model has some shortcomings which we need to correct in our sink terms. Laid out like this, it tells a great story. As it is now, the results section is a bit buried and wafïňĆy. That said, I think the organizational weakness in the results is well mitigated in the discussion section which is very is well constructed and clear (in fact, I enjoyed reading this section greatly more than the rest of the paper).

Figure 2 shows the MODIS-Aqua/Terra 10° N- 20° N climatological AOT as a function of longitude with the July 2007 MODIS-Terra overlaid. This figure shows that the dust barrier has been a persistent feature for nearly 10 years worth of MODIS observations.

We have adopted the suggested restructuring of our results section. We now present the barrier as a persistent phenomenon in Section 3.1. We point to Figure 2 right away as our motivation for using GEOS-5 to explore the observed barrier and use the TC4 observation as a case study for illustrating the barrier and evaluating our simulated dust distributions. We note that our model doesn't quite produce the same barrier sharpness and have essentially removed the "evaluation" aspect of our paper and move directly into investigating the controls on dust transport in Section 4. Section 5 presents our sensitivity study analysis and conclusions are discussed in Section 6.

3. Along the some lines, the paper is prey the common pitfall of many climate model researchers: Trying to understand a high frequency process with monthly statistics. Here it is even worse in that they only have 1 month! Using model with satellite AOT and precipitation data they should demonstrate a speciïňĄc event even more thoroughly. Figure 7 and its associated discussion could be expanded to show satellite precipitation (We like CMORPH for this). I would also combine the AQUA AOT ïňĄeld with Terra as you need to only be qualitative here, getting an exact matchup is not totally necessary.

I would also lay out the GEOS 5 wind and precipitation ïňĄelds.

Our focus on July 2007 is to utilize observations from TC4 field campaign. Figure 2 shows that the observed July 2007 dust barrier is representative of its climatology, so we felt it was reasonable to focus on that month to understand the processes that lead to the barrier. Computational expense prohibited a longer term analysis of this feature. We note this in our introduction:

"We focus on dust transport during summer 2007 in order to exploit aircraft observations made during the NASA TC4 field campaign. The short time period covered in the present investigation is in part a reflection of the computational expense in carrying out high spatial resolution (50 km) global aerosol simulations, but we reach some tentative conclusions about the relative importance of removal and transport mechanisms in establishing this barrier and chart a path for future studies to follow."

The model is run with an internal time step (for chemistry and physics) of 20 minutes. The model precipitation fields are generated at that high time frequency, and the dynamical fields are further updated from analyses every six hours. So, to be clear, we are not driving any aspect of the model from monthly data. We attempt to address the reviewers point here about high frequency events by providing an analysis of one particular event (Figures 4 -6, pertaining to the dust event observed in Central American on July 19). The subsequent analysis of overall system is presented in terms of the monthly mean statistics, which are aggregated from the model's 20 minute time step. We acknowledge that GCMs historically have had problems with precipitation, but this setup allows for an internally consistent formulation of the processes (driving meteorology, precipitation, aerosol transport and removal) used in our experiment. In our conclusions, we note that our results are sensitive to the parameterizations used in our model and the lack of observed wet removal rates prevents us from validating the rates in our model.

Regarding Figure 7 (now Figure 6 after rearranging), we have modified it to combine

ACPD

11, C6544–C6550, 2011

both the Aqua and Terra AOT fields with GPCP daily precipitation overlaid. On the GEOS-5 plot, we overlaid the simulated daily precipitation and the 700 mb wind field at 18Z. Now, the figure clearly shows the dust barrier and a nice illustration of both processes (transport and scavenging) that contribute to the barrier.

From our analysis, we found that scavenging has twice the contribution to the barrier than transport. Of course, the relative contributions of the transport/removal processes to the barrier may vary with time. We discuss this in our conclusion, stating that the barrier is a persistent summertime feature, but our results are only valid for July 2007. We additionally note that we will investigate the effects of intra-annual and inter-annual variability on the relative roles of transport and loss processes in the future.

4. As for other work such as surrounds ïňĄgure 11, I would look for speciïňĄc events which transport into Mexico and Texas, rather than rely on a monthly mean. This is even a good case for trajectories spawned every day in the Caribbean at key model levels. Where do they go? This seems more straightforward to me.

The point of Figure 11 was to illustrate what is happening to the mean dust flow as it is transported away from the Saharan source region. From this, we found that the rotational component of flow acts to recirculate dust towards Mexico/Texas and the divergent component acts to converge dust over the Caribbean where it is likely to be scavenged. This study was focused on what was happening to dust in the Caribbean and for our analysis (Figure 14, Table 1), once dust was transported north of 20° N, we were no longer concerned with what happened to it.

For a particular event, if dust is transport out over the Caribbean to Mexico/Texas, it will eventually be subject to removal from the atmosphere. We have reformatted Figure 10 to show the ratio of wet removal to dry removal (Figure 10a) and the ratio of convective to large-scale scavenging (Figure 10b). While again we show only the monthly mean, it is likely that wet removal and in particular, convective scavenging will dominate over Mexico/Texas.

ACPD
11, C6544–C6550, 2011

5. In regards to their problem with scavenging, monthly means do not give the problem justice. This is why in Xian et al., (2009) we substituted CMORPH precip for model precip in our scavenging routines. Also, it is nice to see that GEOS-5 captures the fact that dust is frequently in the boundary layer, a key PRIDE ïňĄnding that historically models have had difïňĄculty replicating. But this then leads to how dry scavenging is handled in GEOS-5. If parameterized incorrectly, it could induce a huge sensitivity. Given the transport pathway of dust, this could covary with precipitation, confounding the analysis. This should at least be brieïňĆy discussed.

To reiterate, GEOS-5 determines its own precipitation internally at each time step so that is consistent with its driving meteorology (see response to #3). Keeping dust in the boundary layer is one of the significant improvements that we saw moving from GEOS-4 to GEOS-5.

We expect that modifying wet removal in our sensitivity experiments would certainly influence the significance of dry removal rates. We point to the fact that dry removal is most significant near the source region and it becomes less significant downwind. We discuss this in our conclusion:

"Another caveat is that we did not explore the role of dry removal processes, though similar to wet removal, dry removal rates are not well constrained by data. Additionally, we neglected compensating effects in removal rates when removal processes were modified in the sensitivity studies. However, by mass, dry removal becomes less important with distance from the source region. Offline analysis confirmed this, as dry removal rates from our no wet removal simulation increased by a factor of 1.3 when compared to our baseline simulation over the region of the Central American dust barrier."

6. Finally, I understand this paper is as much about GEOS-5/TC4 as the dust phenomenon studied, but I would focus on one.

TC4 provides a framework for our analysis of the Central American dust barrier. After

ACPD

11, C6544–C6550, 2011

Interactive Comment

we found that this is a persistent feature, we then hypothesized that the cause of this barrier is due to scavenging, transport, or a combination. While it may be clear from observations that scavenging definitely has a contribution to this phenomenon, the effects of transport aren't as clear and a GCM simulation (GEOS-5) is a useful tool for determining the relative contributions of each.

We have removed most of the "evaluation" aspects of this paper and instead focus on exploring dust barrier. However, comparing GEOS-5's representation of the barrier to observations, we found an important result: the wet removal in the model needs to be more vigorous to achieve an AOT that closely reproduced the observed barrier. From here, we performed additional tests to see how the relative contribution from removal and transport processes to the barrier changed as removal processes were modified.

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ACPD

11, C6544–C6550, 2011

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