

Interactive comment on “Investigation of the “Elevated Heat Pump” hypothesis of the Asian monsoon using satellite observations” by M. M. Wonsick et al.

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Anonymous Referee #4

Review of paper titled “Investigation of the “Elevated Heat Pump” hypothesis of the Asian monsoon using satellite observations”

This paper investigates the Elevated Heat Pump (EHP) hypothesis on the effects of absorbing aerosol-induced atmospheric warming on the Asian monsoon. Since the
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publication of the EHP hypothesis proposed by Lau et al. 2006, and previous papers on aerosol-monsoon (Menon et al. 2002, Ramanathan et al. 2005), several other climate modeling and observational studies have further explored the role of absorbing aerosols in perturbing large-scale Asian monsoon circulation and rainfall patterns.

The topic of the present manuscript by Wonsick et al is aimed at investigating the EHP hypothesis and is therefore of potential interest to the aerosol-monsoon community. That said, I think there are major issues with the data analysis approach as well as authors’ contradictory interpretations and understanding of EHP and their own results. The observational results presented in the manuscript are weakly portrayed, particularly arising due to lack of statistical robustness of the studied aerosol-convection monsoon relationship. Authors use a very limited dataset and use a highly simplistic approach to investigate the aerosol-monsoon relationship and often use mere superposition of datasets (e.g. aerosol, convection, rainfall) to derive cause and effect. In my opinion, the paper is not suitable for publication in ACP.

Reviewer - Comment

Main concerns:

Very limited dataset is used to investigate the EHP mechanism. MISR Aerosol Optical Depth (AOD) data are used as two pairs of contrasting years in terms of the aerosol loading over northern India. Two years of high AOD and two years of low AOD are selected from the MISR time series of AOD for the 6-year period 2000-2005. The entire analysis of convection and rainfall, and their interpretations related to the EHP mechanism, is based on the 4 years of contrasting aerosol loading. I find the usage of only 4 years of data to investigate the aerosol-monsoon relationship, and the subsequent results, to be seriously lacking in robustness. A longer period is needed for such investigation. Clearly, there are longer records for aerosol, convection and rainfall data before 2000 as well as after 2005. Regarding aerosol data, MISR data itself continues till present, so is MODIS (with TOMS having a longer time series). It should be noted

that MISR has a narrow swath and overpasses the same location once in 7-8 days (compared to daily coverage from MODIS), and therefore has a limited sample size in its monthly mean products.

Authors-Response

Major concern of this Reviewer is the limited dataset used in this study. This is now changed, and we utilize 13 years of data, including the entire record of both MISR and MODIS from 2000 – 2012. Both aerosol data sets are consistent in identifying high and low aerosol years.

Reviewer - Comment

Authors use the upper tropospheric temperature data for April in high and low aerosol loading years to assess the temperature anomaly over the Tibetan Plateau associated with aerosol-induced heating. Authors did not include results for May when the EHP hypothesis predicts a subsequent large temperature anomaly over Tibetan Plateau and the Himalayan foothills in May, unlike the authors' emphasis only on April (section 4.1) related to the upper tropospheric temperature anomaly throughout the manuscript and specifically related to the discussions based on Fig. 5. In fact, the maximum aerosol loading over the Himalayan foothills and the Indo-Gangetic Plains is during May and early June (in observations). Therefore, it is essential to investigate the month of May in terms of the temperature anomaly.

Authors-Response

We have now analyzed May as suggested.

Reviewer - Comment

Authors' investigation of Convection and Rainfall in the foothills of the Himalaya and northern India, and their assertion that these two parameters should be higher in May only is not consistent with EHP, which rests on the precipitation response in May and June. After all, June is the monsoon onset period over India. Climatologically, northern

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India receives monsoon rainfall during latter part of June. Majority of the discussions (section 4.2) on differences in the frequency of occurrence of convection (and Fig. 6a and Fig. 6b) are based on May, which should be discussed for May and June (or May-June together), in order to investigate the EHP in a coherent manner. In fact, Fig. 6c shows the difference in frequency of occurrence of convection, in June, to be higher over northeastern India, along the foothills of the Himalaya (and lower over southern continental India), i.e. consistent with the EHP.

Authors-Response

We acknowledge that the monsoon precipitation normally commences in June in the southern part of India and proceeds northward. However, our discussion of enhanced precipitation in the foothills of the Himalayas and in northern India follow directly from statements made in the original hypothesis. The following is an excerpt from section 3.1 of Lau et al. (2006):

"Notice that in May (Fig. 4c), over central and northern India (15–25° N), due to solar dimming, the air near the surface cools more than the air immediately above it. As a result a stable air mass exists in the lower troposphere, which is likely to inhibit convection. However, the EHP effect appears to be able to By-pass the stable air mass, by drawing in warmer and moister air from the south above the stable air mass (above 700 hPa) and induce convection over the foothills of the Himalayas to the north of the stable air mass."

Later in section 3.2, Lau et al. (2006) state:

"As a result of the aerosol induced upper troposphere warming over the TP, and the lower-level heating and forced ascent over northern India, significant increase in rainfall over northern India (~20° N) is found in May, suggesting an advance of the monsoon rainy season (Fig. 5d)."

In a later publication (Lau and Kim, 2011*), the authors downplay the component of the

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hypothesis that predicts the early onset of the monsoon precipitation in northern India. They state:

“...the possible enhancement of rainfall over the foothills of the Himalayas in May is only a possible early signal which is important for the local population but not critical to the entire outcome of the EHP. We submit that such an increase is still not proven by either NB or LK06, because of the use of coarse resolution GPCP rainfall data set in both analyses. To detect the early response of rainfall in May, there is a need to use high resolution rainfall data such as TRMM (see Figure 1) as well as in situ observations with high temporal resolution to resolve the orographically generated rainfall along the narrow strip over the Himalayan foothills, downstream of the increased low-level meridional flow toward the foothills.”

We do agree with the statement that higher resolution data (in space and time) are needed to better resolve the issues of the EHP. This was one of the motivations for using the high resolution convection data from Meteosat-5; we felt it was worthwhile to report what could be seen in the data.

As for Figure 6c (which is now Figure 11 in the revised manuscript) which shows June precipitation, we acknowledge in our conclusions that the reduced precipitation in southern India in June is observed as hypothesized. We do not specifically address the amount of precipitation in northern India in June, but rather show the overall peak-monsoon season (Jun – Sep) rainfall to assess whether or not the EHP effect increases total seasonal rainfall as predicted.

*Lau, K. M., and Kim, K. M.: Comment on “‘Elevated heat pump’ hypothesis for the aerosol-monsoon hydroclimate link: ‘Grounded’ in observations?” by S. Nigam and M. Bollasina, *J. Geophys. Res.*, 116, D07203, doi:10.1029/2010JD014800, 2011.

Reviewer - Comment

Lines 20-25, Page 10136: Concerning convection in July, authors state “This is contrary

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to the hypothesis, which predicts less precipitation in the low aerosol years”. According to the EHP hypothesis, high aerosol loading years may experience advancement of early monsoon rainfall. I don't think that directly implies low aerosol loading years would experience less precipitation, as the authors are alluding to. Several other factors/parameters such as land-sea gradient, heat fluxes, convective instability, etc, play larger roles than aerosol absorption in affecting the monsoon circulation. I think the Lau et al 2006 paper associates aerosol absorption effects in amplifying the land-sea meridional tropospheric temperature gradient, but at the same time cautions that natural forcing agents play larger role than aerosols.

Authors-Response

The manuscript has been changed and this comment no longer applies to the revised version.

Reviewer - Comment

Figure 9 and Table 1: I find this figure and related discussions on page 10137, and Table 1 and related discussions on page 10139 to be extremely weak. In my opinion, this is a mere superposition of aerosol and rainfall data. Using monthly mean data, a high aerosol loading region cannot be simply taken to be a link in causing less rainfall for that region, and therefore should not be attributed to semi-direct effect. I think that is a dangerous thing to do and unfortunately, in the literature, some papers use a direct correlation between monthly mean aerosol and rainfall to derive semi-direct effect. In fact, high aerosol loading could be simply due to less cloudiness or rainfall occurring over the region, and vice versa, in monthly mean column-integrated satellite data. More detailed work is needed to address and establish semi-direct effect of aerosols on cloudiness, and not just by showing direct correlation.

Authors-Response

We agree that it is very complicated to conclusively establish the semi-direct effect

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of aerosols with observational data. The data presented in Table 1 is not a major conclusion of our paper but we feel it is informative to show that the data are consistent with the explanation given by Bollasina et al. (2008).

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 10125, 2013.