Quantifying the Impact of Missing Aerosol Sources on Long Range Transport and Extreme Events using Satellites and Models

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Over the past two decades there have significant changes in the sources and magnitudes of aerosol emissions. One is from a rapid expansion of energy usage and urbanization in developing regions of Asia, Africa, and South America. The other is from increased deforestation world-wide. In addition to these changes we now have access to many measurements of aerosols on a global-scale from passive to active measurements from satellites and ground stations.

We have successfully proposed a new analytic method (i.e. Lin, Cohen, et al. 2020 [RSE]; Wang, Cohen et al. 2020 [ACP]; Lan, Cohen et al. 2020 [Under Review]) that combines the data from multiple remotely sensed platforms in space and on the ground into a single dataset. Subsequently a variance maximization scheme is applied to this data to analyze how the different sensed and measured variables related to aerosols change in relation to each other. This is then combined with a basic understanding of the physics and chemistry of these different sources and how they should evolve over time. Finally, these are merged together in connection with a traditional Kalman filters techniques to smooth out and scale the results, allowing for us to quantify the magnitudes of the aerosol emissions. Our results have a new a priori for global aerosol emissions from missing sources, or sources which have undergone rapid global change from 2000 to 2020.

However, such extreme changes in aerosol emissions as observed from our results and supported by the underlying measurements lead to significant impacts. First, in cases where a significant amount of the aerosols is lofted to height, there is a strong impact on vertical stability of the atmosphere and hence a feedback which allows for more intense long-range transport. This is demonstrated clearly when our method is used to run the new emissions in the global CESM model. We find that instead of sources from China dominating the plume over the Korean Peninsula and Japan out to the Pacific Ocean, that in fact, there is an even stronger signal from India and Southeast Asia, which itself is transported over Southern Greater China and in turn continues onwards over Japan and the Pacific Ocean. This signal is found to be a significant contribution nearly every year, and the dominant part of the contribution in the February to April system from a climatological perspective. The results of the underlying sources, physics, and dynamics will be presented. Comparisons with other measurements, such as CO from MOPITT will also be used to provide additional support to this assertion. One interesting thing to note is that similar long-range transport is found in other regions of the world as well, including from Indonesia and Central Africa over the Indian Ocean, and from South America over the Atlantic and sometimes even Indian Ocean.

On top of this, we will further analyze the impact that these new sources have on extreme events. While we observe clear decreases in sources from urban North America and urban Western Europe, increases in some parts of East Asia and decreases over other parts of East Asia, on average, in terms of extreme events the same is not true. We have found a significant impact on extreme events from the new sources from North America, Southeast Asia, Africa, and the Arctic. Often these events last from a few days to a few weeks and lead to conditions in areas which otherwise are generally very clean. Some of the feedbacks in terms of the transport and the conditions of the emissions themselves in terms of the vertical distribution will be discussed more fully.

Keywords: Aerosol Emissions, Long Range Transport, Extreme Events, In-Situ Processing

