PM PA Review

Comments on Chapter 5

Tony Cox

October, 2019

Charge question

- **Chapter 5 – Review of the Secondary Standards:** What are the CASAC views on the approach described in chapter 5 to considering the evidence for PM-related welfare effects in order to inform preliminary conclusions on the secondary standards? What are the CASAC views regarding the rationale supporting the preliminary conclusions on the current secondary PM standards?

Comments

- Discussions of several topics (e.g., visibility, materials damage, etc.) are informaive.
- But, the discussion of impacts of PM2.5 changes on climate change is not adequate to support responsible, well-informed policy deliberations and decision-making
  - Plausible impacts are large enough to dominate many other considerations
  - Available quantitative evidence and modeling are not discussed, but are essential for informed policy-making

PA discussion of climate impacts

- p. 5-26 *"While research on PM-related effects on climate has expanded since the last review, there are still significant uncertainties associated with the accurate measurement of PM contributions to the direct and indirect effects of PM on climate."*
- p. 5-35 *"Limitations and uncertainties in the evidence make it difficult to quantify the impact of PM on climate and in particular how changes in the level of PM mass in ambient air would result in changes to climate in the U.S.*
- *Thus, as in the last review, the data remain insufficient to conduct quantitative analyses for PM effects on climate in the current review."*

But climate impacts of PM2.5 are too important and well-studied to skip

- "… Eliminating the human emission of aerosols—tiny, air-polluting particles often released by industrial activities—could result in additional global warming of anywhere from half a degree to 1 degree Celsius.
- This would virtually ensure that the planet will warm beyond the most stringent climate targets outlined in the Paris climate agreement" (Harvey 2018, www.scientificamerican.com/article/cleaning-up-air-pollution-may-strengthen-global-warming/).

PM2.5-temperature interactions

- The PA should also address how changes in cold weather and warm weather temperature extremes due to reduced PM2.5 are likely to affect public health risks
  - Patel D, Jian L, Xiao J, Jansz J, Yun G, Robertson A. Joint effect of heatwaves and air quality on emergency department attendances for vulnerable population in Perth, Western Australia, 2006 to 2015. Environ Res. 2019 Jul;174:80-87
  - Xing J, Wang J, Mathur R, Pleim J, Wang S, Hogrefe C, Gan CM, Wong DC, Hao J. Unexpected benefits of reducing aerosol cooling effects. Environ Sci Technol. 2016 Jul 19;50(14):7527-34.

Quantitative models are available

RESEARCH ARTICLE

ATMOSPHERIC PHYSICS

Substantial convection and precipitation enhancements by ultrafine aerosol particles

Jiwen Fan,[1*] Daniel Rosenfeld,[2] Yuwei Zhang,[1,3] Scott E. Giangrande,[4] Zhanqing Li,[3,5] Luiz A. T. Machado,[6] Scot T. Martin,[7] Yan Yang,[1,8] Jian Wang,[4] Paulo Artaxo,[9] Henrique M. J. Barbosa,[9,10] Ramon C. Braga,[6] Jennifer M. Comstock,[1] Zhe Feng,[1] Wenhua Gao,[1,11] Helber B. Gomes,[12] Fan Mei,[1] Christopher Pöhlker,[13] Mira L. Pöhlker,[13] Ulrich Pöschl,[13,14] Rodrigo A. F. de Souza[15]

Aerosol-cloud interactions remain the largest uncertainty in climate projections. Ultrafine aerosol particles smaller than 50 nanometers ($UAP_{<50}$) can be abundant in the troposphere but are conventionally considered too small to affect cloud formation. Observational evidence and numerical simulations of deep convective clouds (DCCs) over the Amazon show that DCCs forming in a low-aerosol environment can develop very large vapor supersaturation because fast droplet coalescence reduces integrated droplet surface area and subsequent condensation. $UAP_{<50}$ from pollution plumes that are ingested into such clouds can be activated to form additional cloud droplets on which excess supersaturation condenses and forms additional cloud water and latent heating, thus intensifying convective strength. This mechanism suggests a strong anthropogenic invigoration of DCCs in previously pristine regions of the world.

Fan et al., *Science* 359, 411–418 (2018) 26 January 2018

Quantitative data are available

Advances in Atmospheric Sciences October 2019, Volume 36, Issue 10, pp 1047–1059

Characteristics of Surface Solar Radiation under Different Air Pollution Conditions over Nanjing, China: Observation and Simulation

Hao Luo, Yong Han, Chunsong Lu, Jun Yang, Yonghua Wu

Abstract

Surface solar radiation (SSR) can affect climate, the hydrological cycle, plant photosynthesis, and solar power. The values of solar radiation at the surface reflect the influence of human activity on radiative climate and environmental effects, so it is a key parameter in the evaluation of climate change and air pollution due to anthropogenic disturbances. This study presents the characteristics of the SSR variation in Nanjing, China, from March 2016 to June 2017, using a combined set of pyranometer and pyrheliometer observations. The SSR seasonal variation and statistical properties are investigated and characterized under different air pollution levels and visibilities. We discuss seasonal variations in visibility, air quality index (AQI), particulate matter (PM_{10} and $PM_{2.5}$), and their correlations with SSR. **The scattering of solar radiation by particulate matter varies significantly with particle size.** Compared with the particulate matter with aerodynamic diameter between 2.5 μm and 10 μm ($PM_{2.5–10}$), we found that the **$PM_{2.5}$ dominates the variation of scattered radiation** due to the differences of single-scattering albedo and phase function.

Quantitative impact estimates have been available for more than a decade

- "Both theoretical and observational studies have demonstrated that photosynthesis is more efficient under diffuse light conditions. Mercado et al. (2009) used a global model to estimate that **"global dimming" caused by increased global aerosol in the atmosphere enhanced the land carbon sink by one quarter between 1960 and 1999**." https://uk-air.defra.gov.uk/assets/documents/reports/aqeg/pb13837-aqeg-fine-particle-matter-20121220.pdf
- Mercado L.M., Bellouin N., Sitch S., Boucher O., Huntingford C., Wild M., and Cox P.M. (2009). Impact of changes in diffuse radiation on the global land carbon sink. *Nature*, 458, 1014-1017.

EPA has previously reported on aspects of PM2.5 and climate change

- "A number of studies report evidence of **global dimming between the 1960s and the 1980s, followed by an increase in the amount of sunlight reaching the surface during the 1990s to the present** (sometimes referred to as brightening) (e.g., see review in Wild, 2009). Numerous studies suggest that the **observed dimming and brightening trends are caused by changes in aerosol emissions** over time and the interaction of aerosol direct and indirect radiative forcing (Stanhill and Cohen, 2001; Wild et al., 2005; Streets et al., 2006; Ruckstuhl et al., 2008). **See Table 2-4 for a summary of how aerosol interactions affect surface dimming**."

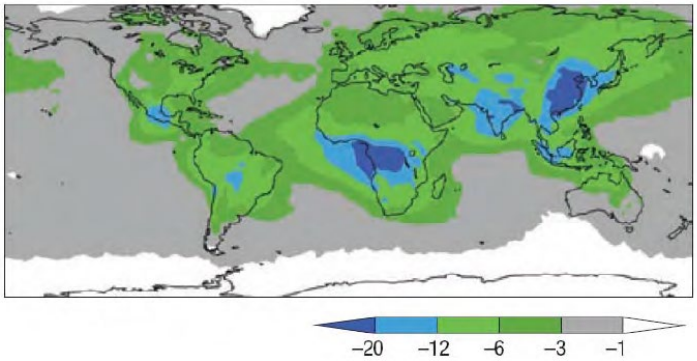


Figure 2-19. Surface Dimming by Anthropogenic Aerosols (W m^{-2}). (Adapted from Chung et al (2005) and Ramanathan and Carmichael (2008).)

Effects	Sign of Change in Surface Dimming	Potential Magnitude	Sign of Change in Precipitation	Potential Magnitude
Cloud albedo effect	Positive	Medium	NA	NA
Cloud lifetime effect	Positive	Medium	Negative	Small
Semi-direct effect	Positive	Large	Negative	Large
Glaciation indirect effect	Negative	Medium	Positive	Medium
Thermodynamic effect	Positive or negative	Medium	Positive or negative	Medium

Table 2-4: Overview of the Different Aerosol Indirect Effects and Their Implications for Global Dimming and Precipitation. This table applies to all aerosols, not just BC. Scientific uncertainty is very low for all effects except the cloud albedo effect (for which uncertainty is low). Table adapted from Table 7.10b in IPCC (Denman et al. 2007). For descriptions of the effects, see Section 2.6.1.2.

Temperature effects have been quantified in multiple countries and studies

1022 JOURNAL OF CLIMATE VOLUMI

Urbanization Effect on the Diurnal Temperature Range: Different Roles under Solar Dimming and Brightening*

KAI WANG, HONG YE, FENG CHEN, YONGZHU XIONG, AND CUIPING WANG

Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, Xiamen, Chin

(Manuscript received 28 December 2010, in final form 11 September 2011)

ABSTRACT

Based on the 1960–2009 meteorological data from 559 stations across China, the urbanization effect on the diurnal temperature range (DTR) was evaluated in this study. Different roles of urbanization were specially detected under solar dimming and solar brightening. During the solar dimming time, both urban and rural stations showed decreasing trends in maximum temperature (T_{max}) because of decreased radiation, suggesting that the dimming effects are not only evident in urban areas but also in rural areas. However, minimum temperature (T_{min}) increased more substantially in urban areas than in rural areas during the dimming period, resulting in a greater decrease in the DTR in the urban areas. When the radiation reversed from dimming to brightening, the change in the DTR became different. The T_{max} increased faster in rural areas, suggesting that the brightening could be much stronger in rural areas than in urban areas. Similar trends of T_{min} between urban and rural areas appeared during the brightening period. The urban DTR continued to show a decreasing trend because of the urbanization effect, while the rural DTR presented an increasing trend. The remarkable DTR difference in the urban and rural areas showed a significant urbanization effect in the solar brightening time.

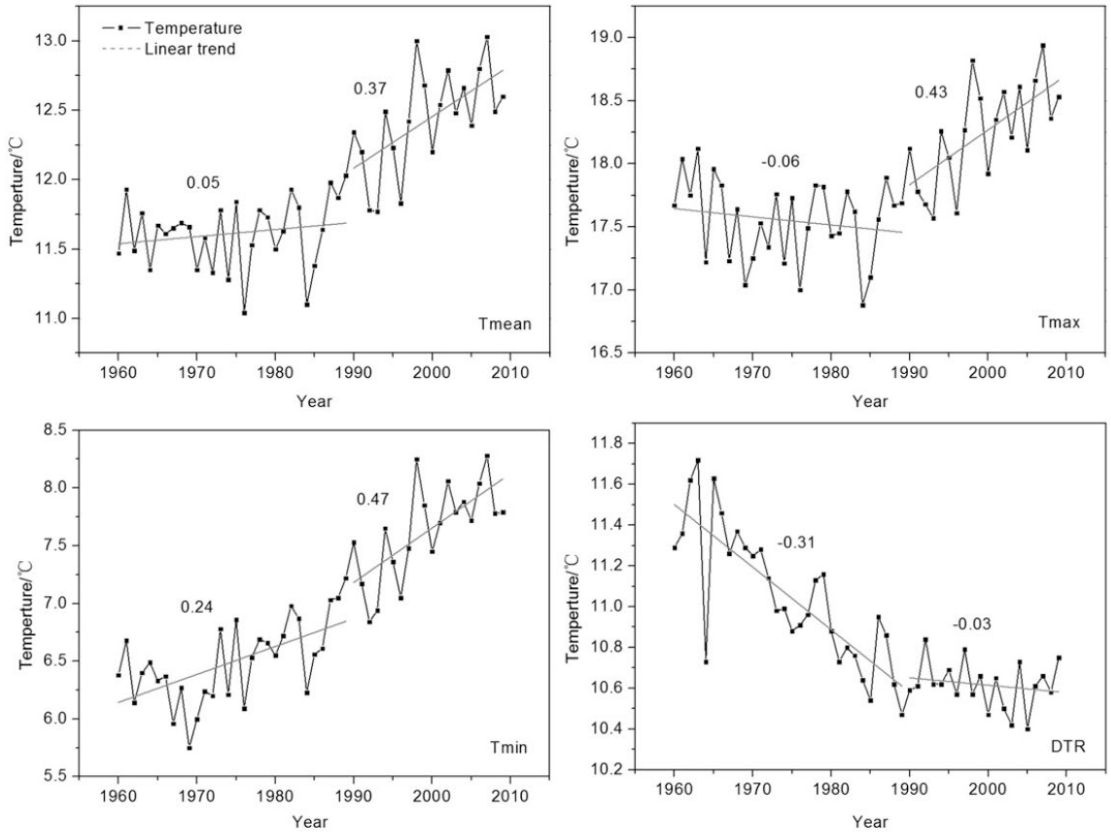
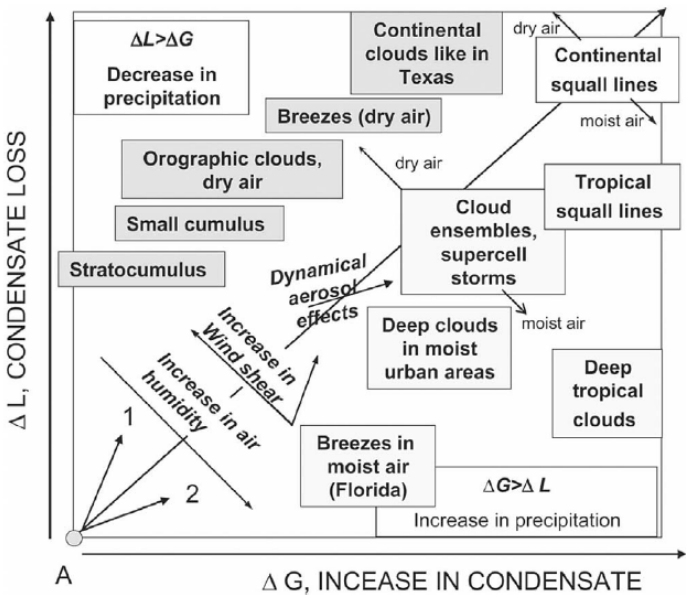


FIG. 3. Annual (top) (left) T_{mean} and (right) T_{max}, and (bottom) (left) T_{min} and (right) DTR of the 52 SSR stations from 1960 to 2009. Dashed lines are linear trends of two periods: 1960–89 and 1990–2009; values are the rates of change (°C decade^{-1}).

Aerosol effects on weather (precipitation, storms, temperatures, etc.) have been modeled quantitatively (e.g., Tao et al. 2012)



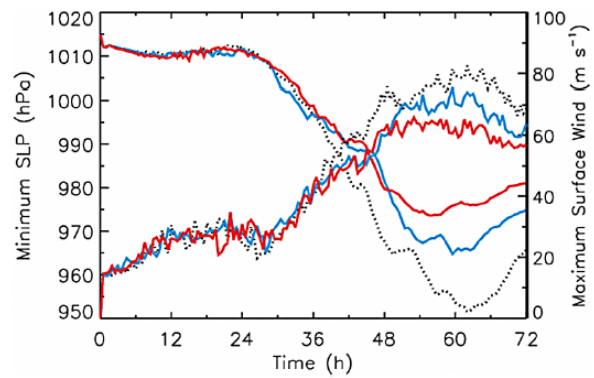


Figure 38. Temporal evolution of the minimum sea level pressure (MSLP) and maximum surface wind for clean (dotted curve), polluted (1000 cm^{-3}, blue curve), and doubly polluted (2000 cm^{-3}, red curve). Adapted from *H. Zhang et al.* [2007].

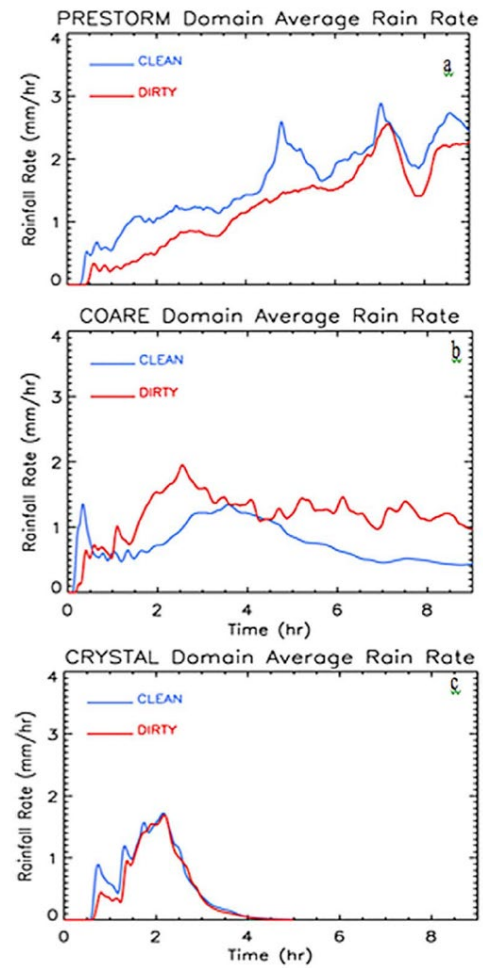


TABLE 5. Examples of Size-Dependent Modules of Anthropogenic Aerosol in Global Interactive Aerosol-Climate Models

Model	Aerosol Model Type	Number of Aerosol Mode/Section	Mixing State	Typical Resolution	References
Stanford	sectional	17	all external or internal	4° × 5°, 22 layers	*Jacobson* [2001]
PNNL-MIRAGE	two-moment modal	4	all external or internal	2.8° × 2.8° (T42), 24 layers	*Easter et al.* [2004]
ECHAM-HAM	two-moment modal	7	all external or internal	1.8° × 1.8° (T63), 31 layers	*Vignati et al.* [2004], *Stier et al.* [2005]
MIT-NCAR	two-moment modal	7	external + core-shell + internal	2° × 2.5°, 26 layers	*Kim et al.* [2008]
PNNL/UMich/NCAR	two-moment modal	13	all external or internal	2° × 2.5°, 26 layers	*Wang et al.* [2009]
GISS-MATRIX	quadrature in moment, two-moment implementation	16	external + internal	4° × 5°, 23 layers	*Bauer et al.* [2008], *McGraw* [1997]

Conclusions

- The PA should inform policy makers about effects of changes in PM2.5 on…
  - Warming, dimming, and brightening
  - High and low (dangerous) daily temperatures
  - Resulting public health impacts related to daily temperatures
  - Land carbon sink capacity
  - Crop yields, agricultural productivity
  - Other weather variables: Precipitation, storms, wind, etc.
- These could well be relatively large effects that should be important in setting secondary standards.
- It is important to provide policy makers with the best and most up-to-date scientific information about them.
  - Considerable data and models are now available to do so