The Impacts of Regional Precipitation Changes on Future Aerosol Burdens in Global Climate Simulations

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Introduction

Air pollution poses a serious threat to human health, and even mild pollution events can cause respiratory infections, heart disease, lung cancer and stroke. The World Health Organization estimates that 4.2 million people die every year from exposure to fine particulate matter (PM2.5) aerosol alone.[1]

As the climate system adjusts to increases in the concentration of greenhouse gases, meteorological conditions such as rainfall are expected to change in ways that may influence the removal of aerosol particles in the atmosphere. Precipitation has a unique role in removing atmospheric pollutants by wet deposition through the processes of in- and below-cloud scavenging. Consequently, the projected effectiveness of these atmospheric "cleansing" events is in question, which may affect future air quality, even without changes in aerosol emissions.

Research Question

Recent studies using Earth system models project the frequency of intense precipitation events will increase as the frequency of light-to-moderate events are reduced on a global-scale, and a few studies have looked at the consequences of these changes for aerosol pollution.[2] However, simplifications in conventional Earth system models used in these studies often poorly represent the frequency and intensity of precipitation, leading to uncertainties in aerosol removal. This is supported by the recently released 4th National Climate Assessment, which highlights regional precipitation uncertainty.

In this study, we apply an alternative approach to address this problem using a model in which the representation of precipitation is improved when conventional convective parameterizations are replaced by high resolution cloud resolving models ("cloud super-parameterization").[3] Our research endeavors to understand how shifting precipitation patterns and characteristics impact air quality changes around the globe using advanced modeling techniques.

Where will aerosol concentrations be affected by changing rainfall frequency and intensity from greenhouse gas driven influences on the climate system?

Methods

In this study, we assess simulations from conventional (CAMv5) and super-parameterized (SPCAMv4) versions of the Community Atmosphere Model. Both simulations were driven by 21st century greenhouse gases from the RCP8.5 scenario. CAMv5 also included an interactive treatment of aerosol, but emissions were held fixed at present values to isolate the influences of meteorological changes.

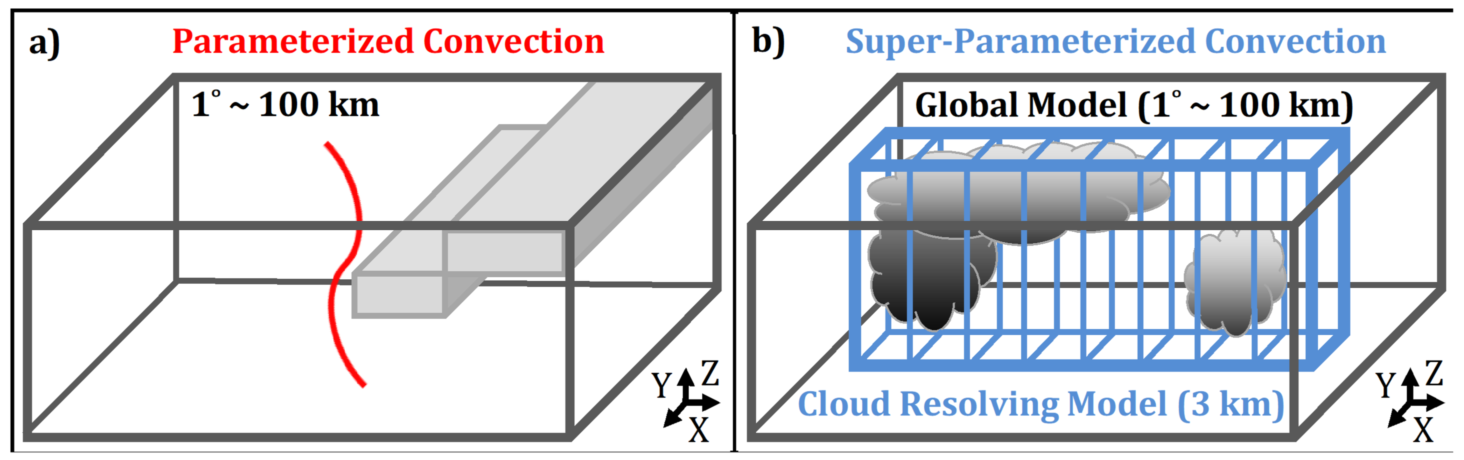

Figure 1. By using high resolution cloud-resolving models, we can more accurately represent convection at smaller scales. Super-parameterization is a computational technique in Earth system model development which allows us to examine small scale cloud processes for the first time.

Air Quality Results

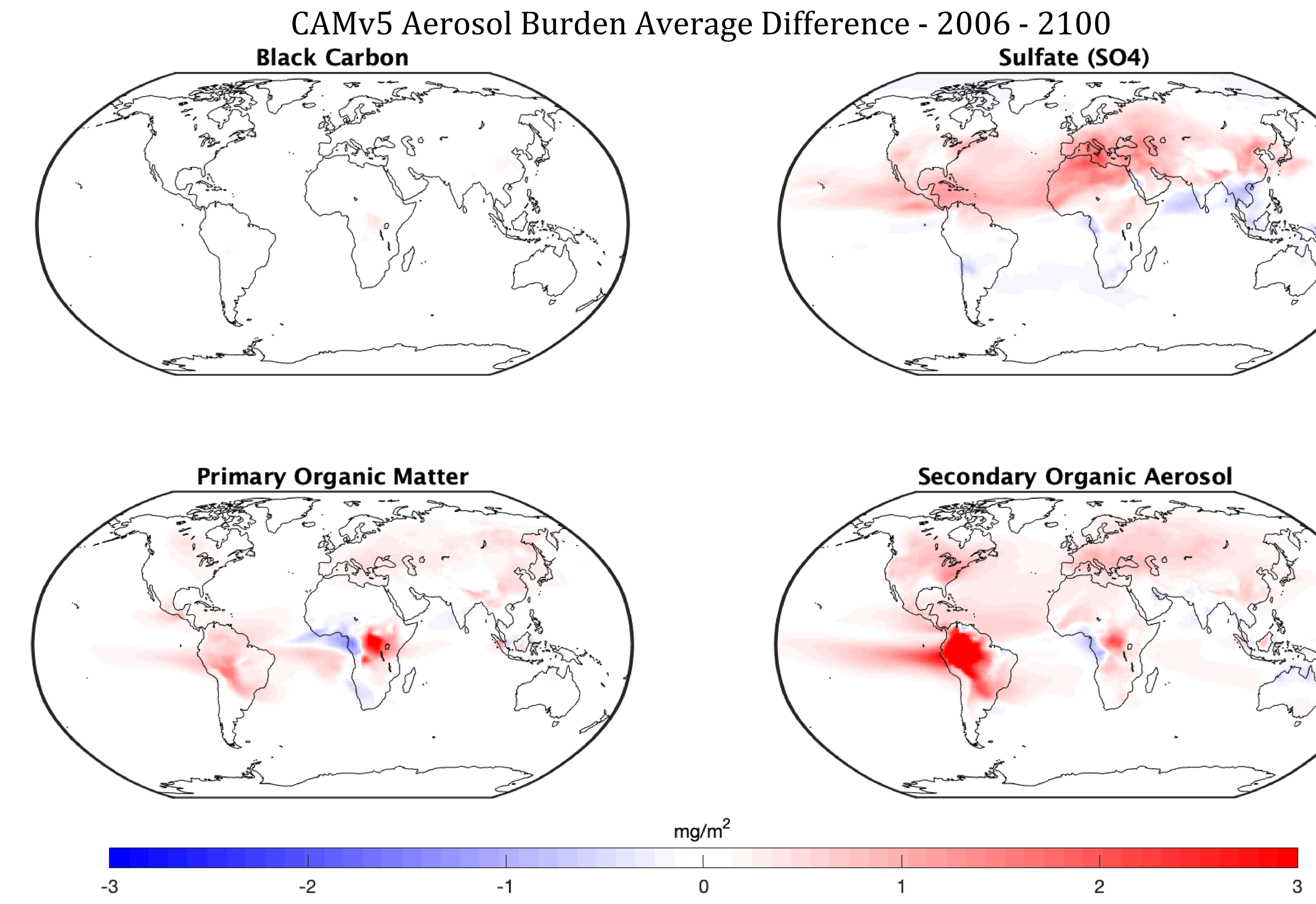

Figure 2. Projected changes in aerosol burden in the atmosphere from 2006 to 2100 via CAMv5.

- Using the traditional model, we see an overall increase in average aerosol burden for these four species. This includes small, hazardous air pollution (PM2.5) as well as coarse particles that affect processes such as aerosol nucleation, aqueous chemistry, and in-cloud/below-cloud scavenging.
- Note the strong average increases of Sulfate in the northern hemisphere and Primary/Secondary Organic Aerosol (POM and SOA) over tropical land masses.

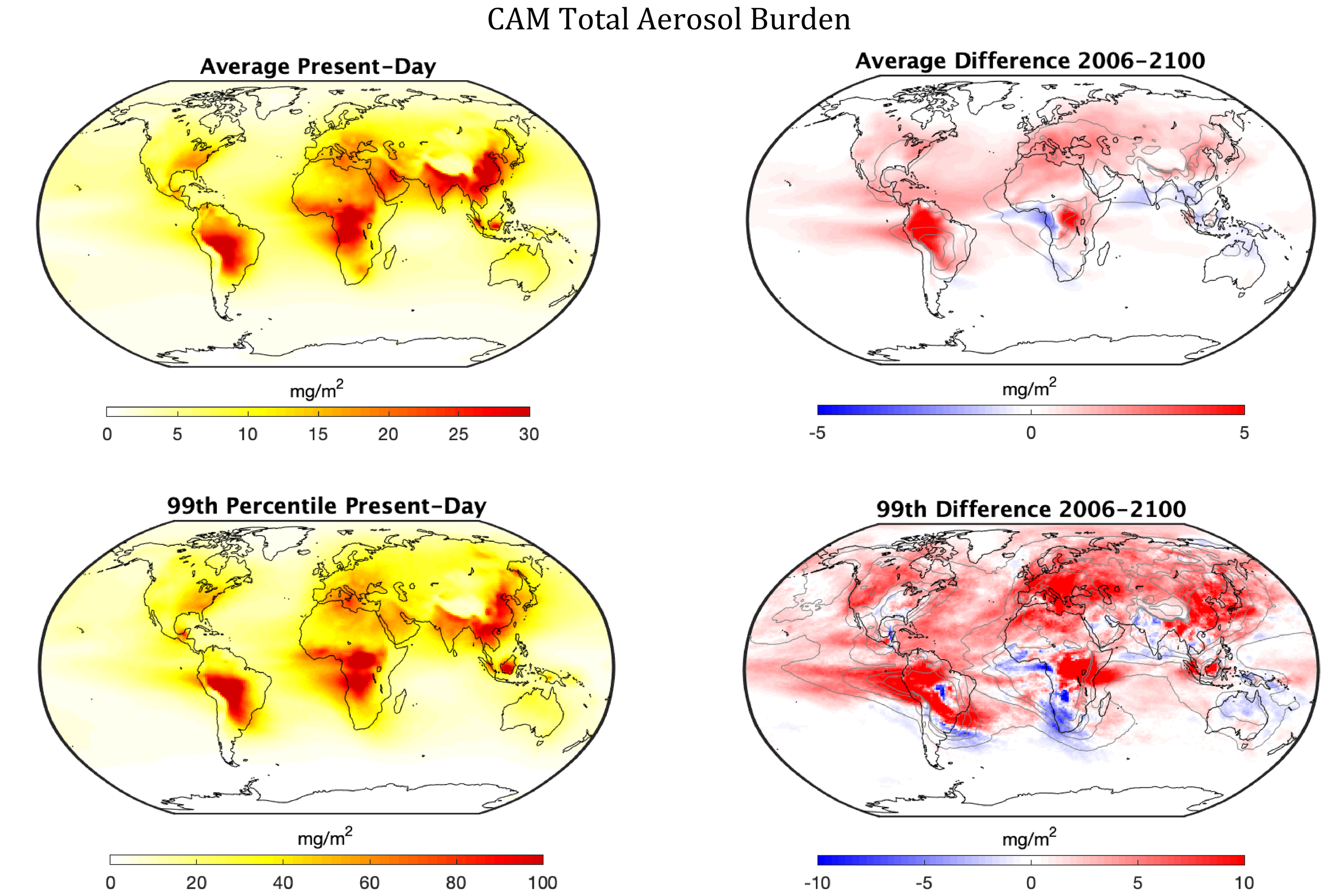

Figure 3. Total aerosol burden (SOA, POM, BC, and SO4) from 2006-2100 in CAMv5 (mg/m^2). This includes annual averages (Top) as well as 99th percentile extreme air quality days (Bottom). Contour lines denote present-day totals.

- Total burden has widespread increase across the Northern Hemisphere
- Note that South American aerosol burden is increasing towards the north of the continent relative to the present day regional maximum.

Precipitation in CAM and SPCAM

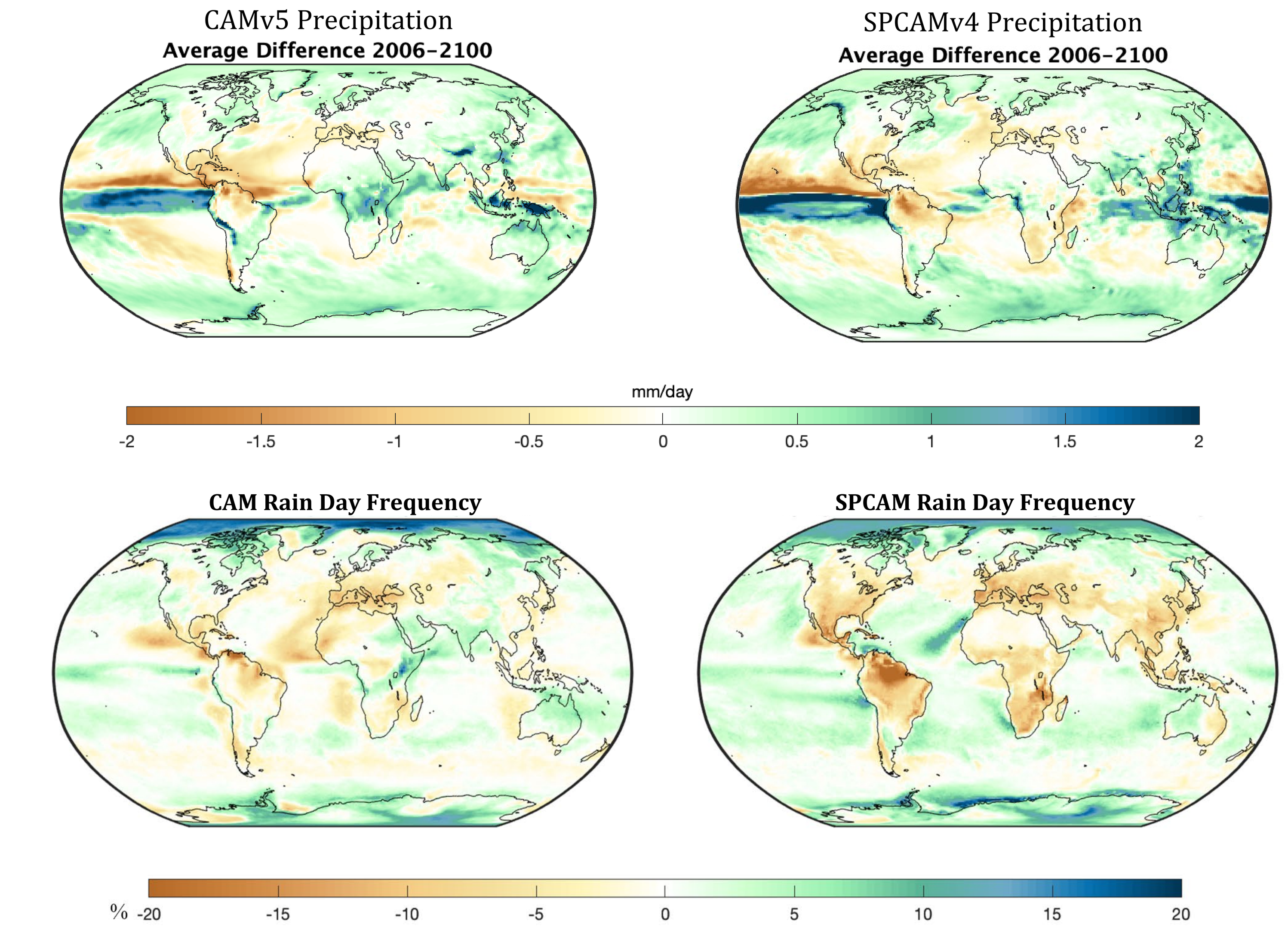

Figure 4. (Top) Average precipitation (mm/day) events in the conventional and super-parameterized model. **(Bottom)** The evolution of precipitation (<.1mm/day to %), shown in rain day frequency between 2006-2100 in CAMv5 and SPCAMv4.

- CAMv5 precipitation changes influence CAMv5 aerosol burden changes more so with frequency (as seen in Central Africa).
- When clouds and rainfall are resolved, we see larger changes in frequency of precipitation such that aerosol burden may be even larger than previously expected in association with those changes. This is particularly evident in the tropical land regions identified (South America and Central Africa).

Conclusions

- Our preliminary research yields clear precipitation changes up until the end of the 21st century in both versions of the model. We find that the representation of cloud processes impacts the patterns of precipitation changes, and therefore may influence changes in air quality on regional-scales.
- The results of the current analysis presented here have motivated ongoing research with SPCAMv5 to assess air quality changes in a model that is both convective permitting and has interactive aerosol.

References and Acknowledgements

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