Global modeling and analysis of key processes controlling the number abundance of tropospheric aerosols

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Abstract

Aerosols are major atmospheric constituents that influence air quality and affect climate. We propose to study the fundamental processes that control the abundance of climate relevant particles in the Earth's troposphere, focusing on new particle formation and subsequent microphysical aging as well as possible feedback mechanisms. The proposed work involves 3-D modeling using a global chemistry model (Harvard GEOS-Chem) coupled with an aerosol microphysics model. The modeling results will be analyzed and compared with relevant field measurements and satellite data. The primary thrusts of the proposed research will address three key questions: 1. What are the key parameters controlling the formation of secondary aerosols in the troposphere, and what are the spatial distributions and temporal variations of new particle formation? 2. What is the microphysical fate of newly formed particles and their probability of maturing into cloud condensation nuclei? 3. How do atmospheric aerosol concentrations respond to changes in Earth's climate, solar activity, and global emissions?

The first question is aimed at resolving a persistent uncertainty concerning the major sources of global aerosols. We will apply a recently developed nucleation sub-module (containing options to use various hypothesized nucleation mechanisms) to study particle formation in the troposphere. Existing land, ship, and aircraft based measurements related to nucleation will be analyzed and compared with 3-D model calculations. To address the second question, we will couple a size and composition resolved aerosol microphysics model with GEOS-Chem. The spatial and seasonal variations of particle number and size properties and the role of long-range transport will be investigated. Various aerosol properties derived from the simulated particle size distributions will be compared with Satellite measurements. The third question deals with long-term changes in aerosol abundance and potential important feedback mechanisms involving nucleation. Our preliminary studies indicate the existence of a positive feedback involving nucleation (global warming → reduced nucleation and aerosol abundance → less aerosol cooling → more warming). We also find that the effect of solar activity on climate can be amplified through the influence of cosmic ray ionization on particle formation and a positive nucleation feedback. These important processes will be comprehensively investigated during this project.

This study will seek to develop, in addition to a better understanding of basic aerosol physics and atmospheric chemistry feedbacks, useful and practical numerical algorithms for incorporating such processes in predictive models.