Assessment of aerosol and cloud characteristics and their effects on surface radiation using in situ instruments, satellites, and models

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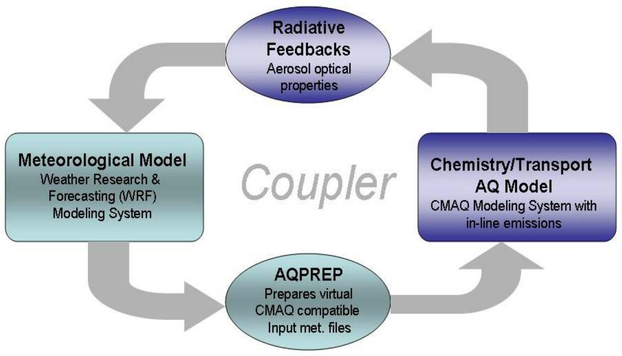
ASR Atmospheric System Research

Introduction

ASR Project – *Evaluation of the Interactions Among Tropospheric Aerosol Loading, Radiative Balance, Clouds, and Precipitation:* A DOE-EPA IAG

The goal of this project is to evaluate the capability of the 2-way WRF-CMAQ model to accurately represent the effects of aerosol loading on radiative forcing over the past 20 years during which there were substantial reductions in aerosol precursor emissions (e.g. SO_2, NO_x) in North America and Europe.

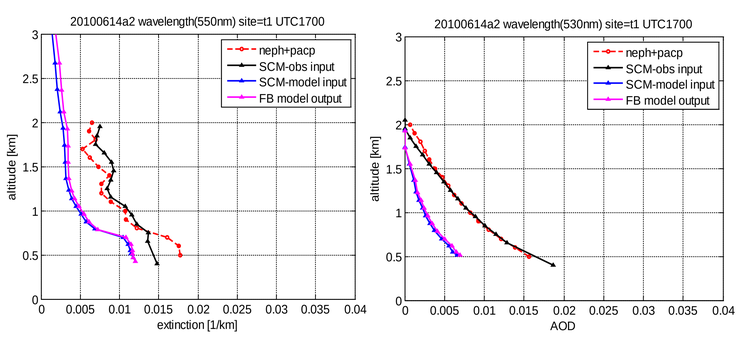
The 2-way coupled meteorology and air quality model is composed of the Weather Research and Forecasting (WRF) model and the Community Multiscale Air Quality (CMAQ) model. The coupled model system runs as a single executable with 2-way data communication between the WRF and CMAQ components via buffer files, which requires minimal changes to either model.



Design of WRF-CMAQ Coupled Modeling System

Direct Aerosol Radiative Effects

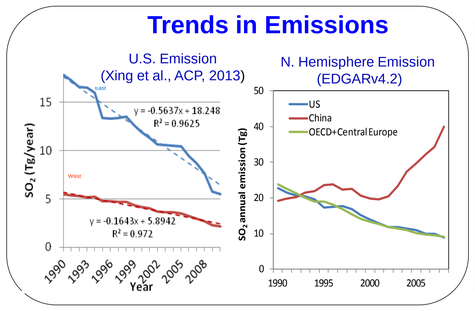
Efficient Mie scattering algorithms have been developed to calculate aerosol optical properties (aerosol optical depth, single scattering albedo, and asymmetry factor) using aerosol mass, chemical composition, and modal size distributions computed by CMAQ. Black carbon is treated by the core-shell approach developed by Frank Binkowski based on Bohren and Huffman (1983)

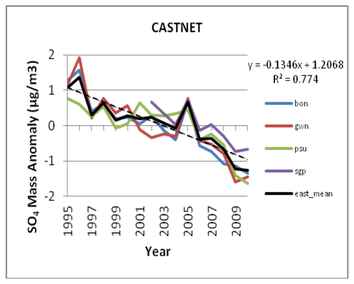


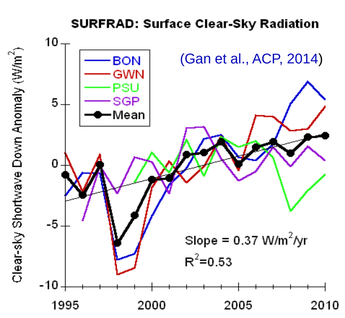
Single column model (SCM) tests comparing computed aerosol extinction to measurements from DOE G1 during the CARES campaign.

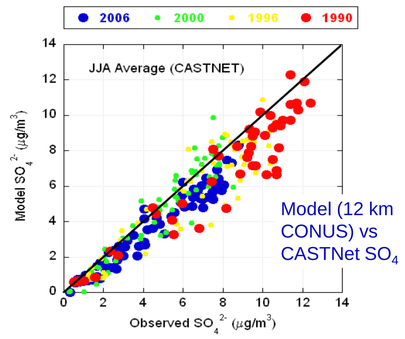
SCM tests show that the aerosol optics model calculations compare well with measurements when using measured aerosol concentrations, size, and composition but does not compare well when using modeled aerosol inputs.

Multi-decadal trends



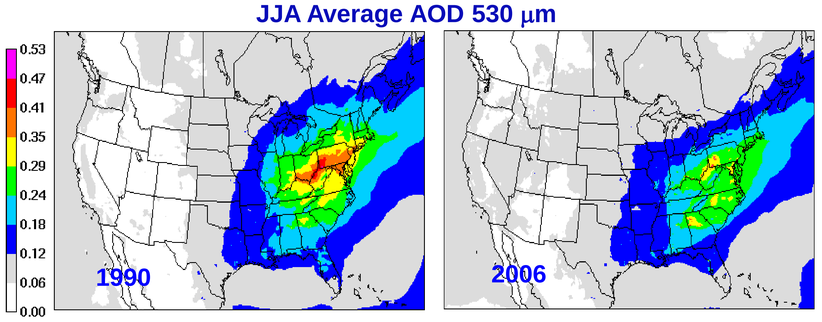






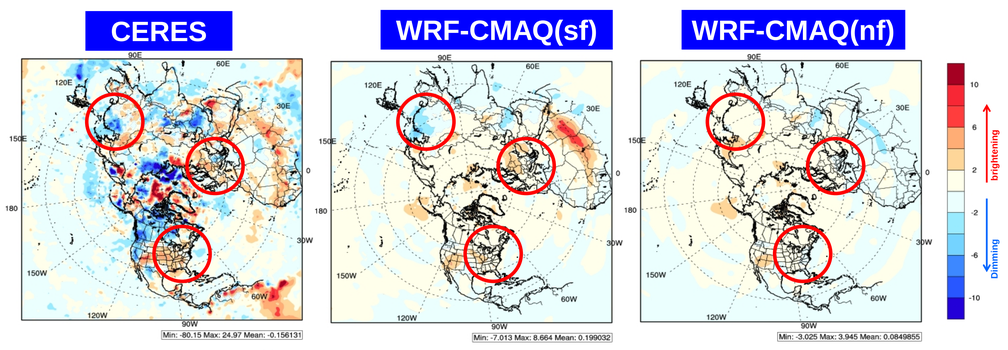
WRF-CMAQ - 12 km

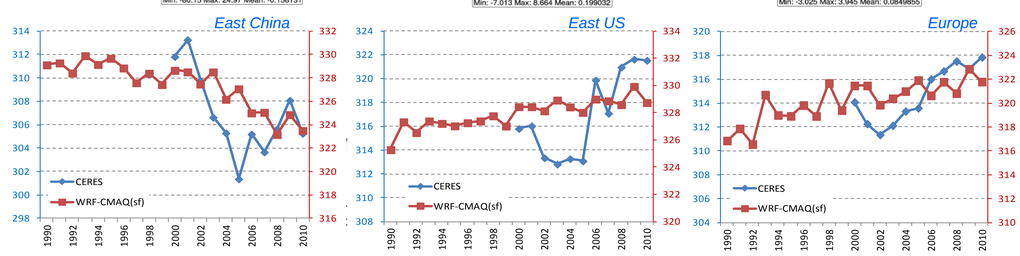
JJA Average AOD 530 µm



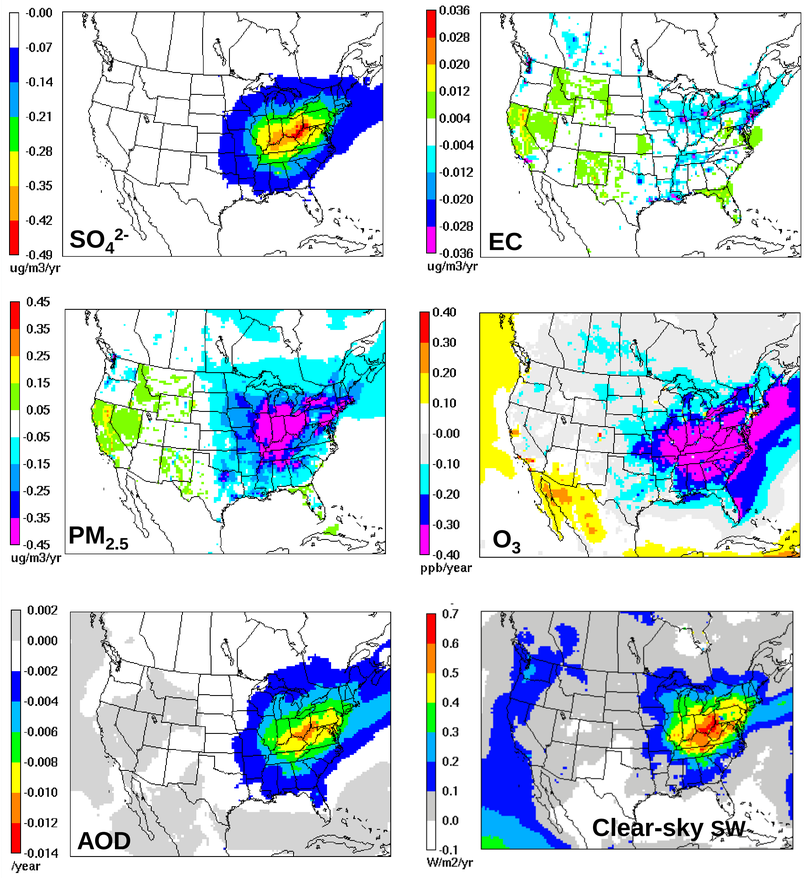
WRF-CMAQ – Hemispheric 108 km

*JJA-average (**2009 minus 2000**)*

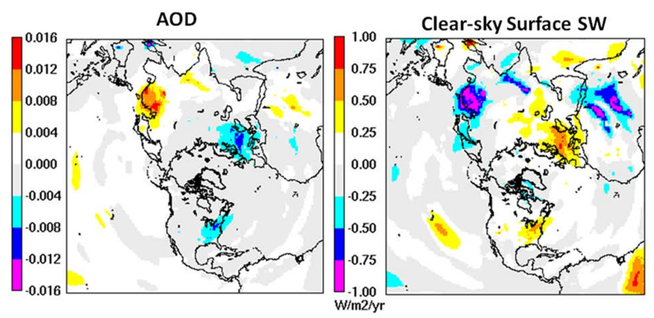




WRF-CMAQ – 36 km



Summer (JJA) trends over the period 1990 – 2010 computed from 36 km resolution WRF-CMAQ with direct aerosol radiative effects for 14 of the 21 years.



Summer (JJA) Trends over the period 1990 – 2010 computed

Summary

- Modeled SW aerosol extinction agrees well with measurements when measured aerosol characteristics are used as input to the SCM
- 2-way coupled WRF-CMAQ simulations for Northern Hemisphere (108 km) and North America at two resolutions (36 km and 12 km) show significant trends in concentrations and radiation over 1990 - 2010 period
- North America and Europe have large decreasing trends in aerosol resulting in radiation brightening
- East Asia has large increasing trends in aerosols resulting in radiation dimming.
- Modeled radiation trends generally agree with satellite (CERES) and surface (SURFRAD) measurements