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LLNL Scientists Use NERSC to Advance Global Aerosol Simulations

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NERSC News

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While “greenhouse gases” have been the focus of climate change research for a number of years, DOE’s “Aerosol Initiative” is now examining how aerosols (small particles of approximately micron size) affect the climate on both a global and regional scale.

Scientists in the Atmospheric Science Division at Lawrence Livermore National Laboratory (LLNL) are using NERSC’s IBM supercomputer and LLNL’s IMPACT (atmospheric chemistry) model to perform simulations showing the historic effects of sulfur aerosols at a finer spatial resolution than ever done before. Simulations were carried out for five decades, from the 1950s through the 1990s.

The results clearly show the effects of the changing global pattern of sulfur emissions. Whereas in 1950 the United States emitted 41 percent of the world’s sulfur aerosols, this figure had dropped to 15 percent by 1990, due to conservation and anti-pollution policies. By contrast, the fraction of total sulfur emissions of European origin has only dropped by a factor of 2 and the Asian emission fraction jumped six fold during the same time, from 7 percent in 1950 to 44 percent in 1990.

Under a special allocation of computing time provided by the Office of Science INCITE (Innovative and Novel Computational Impact on Theory and Experiment) program, Dan Bergmann, working with a team of LLNL scientists including Cathy Chuang, Philip Cameron-Smith, and Bala Govindasamy, was able to carry out a large number of calculations during the past month, making the aerosol project one of the largest users of NERSC resources. The applications ran on 128 and 256 processors.

The objective was to assess the effects of anthropogenic (man-made) sulfate aerosols. The IMPACT model calculates the rate at which SO_2 (a gas emitted by industrial activity) is oxidized and forms particles known as sulfate aerosols. These particles have a short lifespan in the atmosphere, often washing out in about a week. This means that their effects on climate tend to be more regional, occurring near the area where the SO2 is emitted.

To accurately study these regional effects, Bergmann needed to run the simulations at a finer horizontal resolution, as the coarser resolution (typically 300km by 300km) of other climate models are insufficient for studying changes on a regional scale. Livermore’s use of CAM3, the Community Atmospheric Model which is a high-resolution climate model developed at NCAR (with collaboration from DOE), allows a 100km by 100km grid to be applied. NERSC’s terascale computing capability provided the needed computational horsepower to run the application at the finer level.

Depending on their composition, aerosols can either scatter or absorb sunlight, thereby cooling the Earth and acting as a counter to the warming effects of greenhouse gases.

Greenhouse gases such as carbon dioxide are much more longer-lived, so they stay in the atmosphere and have more uniform distribution. But since global warming has not increased as much as some computer models predict based on greenhouse gases alone, scientists have become more interested in aerosols and their possible role in countering some effects of greenhouse gases.

The atmospheric concentrations of both aerosols and greenhouse gases have increased over the past century and, because of their effects on shortwave and longwave radiation (which are partially offsetting), have presumably upset to some degree the thermal equilibrium of the climate system. While satellite measurements and field studies provide vital information to document the global and regional climate impacts by aerosols and greenhouse gases, accurate climate model simulations are an equally important tool in quantifying the radiative forcing as well as identifying and analyzing the climate response.

By running numerous calculations at finer resolution, the team was able to see the cooling effects by region, and to see more differences in the effects of varying concentrations.

The simulations also gave the team an opportunity to test new meteorological data generated using NCAR's CAM3. This model calculates the various factors influencing climate, such as winds, temperatures and precipitation. This data, which bordered on the terabyte scale, was also generated at NERSC.

The LLNL researchers then used the climate data to drive their chemistry model known as IMPACT. By varying the SO_2 emissions levels while running IMPACT, the team was able to simulate different scenarios for each decade, analyze aerosol distributions from each simulation and then examine their effects on radiative forcing (change in energy balance where positive forcing tends to have a warming effect and negative forcings tend to have a cooling effect on climate) at regional scales.

The figure shows the predicted effects on shortwave radiation (watts/m^2) due to anthropogenic sulfate aerosols in the 1950's (top left), 1970's (top right), 1980's (bottom left), and 1990's (bottom right). Note the increased regional cooling effects in central Asia, India, and particularly eastern Asia.

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