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Regional and Global Implications Discovered Using Advanced Transmission Electron Microscopy at the Nanoscale

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Nanoscience is a unique field of science. It is not atomic science, nor a science relevant to bulk materials. For most Earth materials, including gases and fluids, nanoscience is generally relevant in the size range of a few to several tens of nanometers, the size in which these materials do not behave like small molecules or bulk materials. Now well into the 21st century, there are many experimental, analytical, and theoretical/computational tools that have allowed us to understand what this behavior is, and why it might be important or even critical in the overall understanding of how Earth systems behave. In this presentation, I will concentrate on advanced transmission electron microscopy used for 2-D and 3-D imaging, chemical analysis all the way down to the sub-nanometer scale, and electron diffraction that provides crystallographic analysis and phase identification in the nanoscale. I will demonstrate the importance of this information in two examples, one relevant to the local to global scale, and the second relevant to the global scale. The first example has to do with our discovery (using TEM's multiple capabilities) that TiO_2 (rutile/anatase), a very common minor component of coal, converts to titania suboxide (Ti_x0_{2x-1}) nanoparticles during coal combustion in coal fired power plants. We later determined that these suboxides are toxic in the lungs of mice and humans, and these particles are emitted to the local and regional atmosphere from power plants that do not have appropriate dust collectors. The second example concerns ocean iron fertilization techniques to build phytoplankton populations in certain portions of the global ocean system in order to bring down atmospheric CO_2 concentrations at the gigaton scale. This would help to mitigate global warming. Such scenarios have been tested in the oceans and the results have been very promising. One of the outlying questions has to do with the type of iron-containing fertilizer that will be most effective and safe. Nanoparticle fertilizers (both natural and synthetic) are leading candidates, and the TEM assessments of these particles and their interaction with phytoplankton are essential in this field of research.