Linking Plume-Scale Processes to Global Aerosols:
Parameterization of Aerosol Formation and Growth in Coal-Fired Power-Plant Plumes

New-particle formation in the plumes of coal-fired power plants and other anthropogenic sulphur sources may be an important source of particles in the atmosphere. It has been unclear how best to reproduce this plume-scale new-particle formation in global and regional aerosol models with grid-box lengths that are tens of kilometres and larger. These models have therefore made crude assumptions about the sub-grid physics that do not depend on the nature of the source or the ambient conditions, both of which affect the plume chemistry and physics in reality. The predictive power of these models has thus been limited by the resultant uncertainties in aerosol size distributions (Pierce and Adams, 2009).

We have implemented online TOMAS (Adams and Seinfeld, 2002) aerosol microphysics into the SAM Large-Eddy Simulation / Cloud-Resolving Model (Khairoutdinov and Randall, 2003). This SAM-TOMAS model is evaluated against aircraft observations of new-particle formation in two different power-plant plumes and reproduces the major features of the observations (Stevens et al, 2012). We show how the downwind plume aerosols can be greatly modified by both meteorological and background aerosol conditions.

Based on the results of the SAM-TOMAS model, we develop the Predicting Particles Produced in
Power-Plant Plumes (P6) (Stevens and Pierce, 2013) parameterization: a computationally-efficient, but physically-based, parameterization that predicts the characteristics of aerosol formed within sulphur-rich plumes based on large-scale mean meteorological parameters, emissions directly from the source, and mean background pollutant concentrations.

Finally, we implement the P6 parameterization in the GEOS-Chem-TOMAS and GLOMAP global chemical-transport models in order to evaluate the contribution of coal-fired power plants globally to particle number and CCN concentrations (Stevens and Pierce, 2014). Globally, use of the P6 parameterization results in predicted CCN concentrations smaller than or similar to previous sub-grid sulphate schemes depending on the model configuration. We find that the sub-grid scale new-particle formation predicted by P6 is most sensitive to uncertainties in the model-predicted aerosol condensation sink. For constant SO_2 emissions, fewer new particles are formed in more polluted regions. This spatial heterogeneity in new-particle formation cannot be resolved by previous treatments of sub-grid sulphate but is captured by P6.

References:

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