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Dealing with non-unique and non-monotonic response in particle sizing instruments

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A number of instruments used as de-facto standards for measuring particle size distributions are actually incapable of uniquely determining the size of an individual particle. This is due to non-unique or non-monotonic response functions. Optical particle counters have non monotonic response due to oscillations in the Mie response curves, especially for large aerosol and small cloud droplets. Scanning mobility particle sizers respond identically to two particles where the ratio of particle size to particle charge is approximately the same. Images of two differently sized cloud or precipitation particles taken by an optical array probe can have similar dimensions or shadowed area depending upon where they are in the imaging plane.
A number of methods exist to deal with these issues, including assuming that positive and negative errors cancel, smoothing response curves, integrating regions in measurement space before conversion to size space and matrix inversion.
Matrix inversion (also called kernel inversion) has the advantage that it determines the size distribution which best matches the observations, given specific information about the instrument (a matrix which specifies the probability that a particle of a given size will be measured in a given instrument size bin). In this way it maximises use of the information in the measurements. However this technique can be confused by poor counting statistics which can cause erroneous results and negative concentrations. Also an effective method for propagating uncertainties is yet to be published or routinely implemented.
Her we present a new alternative which overcomes these issues. We use Bayesian methods to determine the probability that a given size distribution is correct given a set of instrument data and then we use Markov Chain Monte Carlo methods to sample this many dimensional probability distribution function to determine the expectation and (co)variances - hence providing a best guess and an uncertainty for the size distribution which includes contributions from the non-unique response curve, counting statistics and can propagate calibration uncertainties.