Source Characterization of Atmospheric Releases using Quasi-Random Sampling and Regularized Gradient Optimization

Bhagirath Addepalli, Christopher Sikorski, and Eric R. Pardyjak

UUCS-09-001

Department of Mechanical Engineering
School of Computing
Department of Mechanical Engineering
University of Utah
Salt Lake City, UT 84112 USA

January 28, 2009

Abstract

In the present work, an inversion technique to solve the atmospheric source characterization problem is described. The inverse problem comprises characterizing the source (x, y and z coordinates and the source strength) and the meteorological conditions (wind speed and wind direction) at the source, given certain receptor locations and the concentration values at these receptor locations. A simple Gaussian plume dispersion model for continuous point releases has been adopted as the forward model. The solution methodology for this nonlinear inverse problem consists of Qausi-Monte Carlo (QMC) sampling of the model parameter space and the subsequent application of gradient optimization. The purpose of conducting QMC sampling is to provide the gradient scheme a good initial iterate to converge to the final solution. A new misfit functional that computes the L_∞-norm of the ratio of the observed and predicted data has been developed and was used in the QMC search stage. It has been demonstrated that the misfit functional developed, guides the inversion algorithm to the global minimum. Quasi-random sampling was performed using the Hammersley point-set in its original, scrambled and randomized form. Its performance

was evaluated against the Mersenne-Twister uniform pseudo-random number generator in terms of the speed and quality of the initial iterate provided. Regularized Newton′s method with quadratic line-search was employed for gradient optimization. The standard Tikhonov stabilizing functional was used for regularization and the regularization parameter was updated adaptively during inversion. The proposed approach has been validated against both synthetic and field experiment data. Results obtained indicate that the proposed approach performs exceedingly well for inverse-source problems with the Gaussian dispersion equation as the forward operator. Also, the work presented highlights the advantages of using deterministic low-discrepancy sampling compared to the conventional pseudo-random sampling to solve the source-inversion problem.