Geophysical Research Abstracts, Vol. 9, 09547, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-09547

Evolutionary optimization of an in-situ remediation system - Problem encoding and uncertainty

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The development and calibration of numerical computer models for the simulation of environmental systems is typically not self-serving. From the viewpoint of a practitioner its usefulness lies in quantitative predictions of the system's response to naturally or anthropogenically induced changes in order to aid decision-making. In this study we use two-dimensional model simulations for the cost-optimal design of funnel-and-gate systems. The latter are a passive in-situ treatment option for contaminant plume management. As computational efficiency is a limiting factor for optimization exclusively advective transport is considered. The overall design problem appears as a non-separable, multi-modal, non-linear optimization problem, that is complicated by the fact that numerical model discretization only allows an evaluation of the search space in discrete steps, if adaptive grid-refinement is not available. The problem is approached with evolutionary algorithms, which work derivative-free and show good global optimization properties. More specifically, a simple genetic algorithm and the evolution strategy with covariance matrix adaptation (CMA-ES) are used. Within the scope of the latter algorithm, we explore the benefit of different problem encodings, i.e. different parameterizations of a funnel-and-gate design. Additionally, we consider optimization under uncertainty by the use of a matrix-based first-order second-moment model, that assumes hydraulic conductivity to follow a log-normal distribution. Based on this formulation we are able to efficiently approximate the trade-off curve between cost-optimality and design reliability.