Texas A & M University and U.S. Bureau of Reclamation
Hydrologic Modeling Inventory
Model Description Form
JUNE 18, 1999

Name of Model: UCODE

Model Type: universal inversion code

Model Objective(s):

UCODE performs inverse modeling, posed as a parameter-estimation problem, using nonlinear regression. Any application model or set of models can be used; the only requirement is that they have numerical (ASCII or text only) input and output files and that the numbers in these files have sufficient significant digits. Application models can include pre-processors and post-processors as well as models related to the processes of interest (physical, chemical, and so on). An estimated parameter can be a quantity that appears in the input files of the application model(s), or that can be used in conjunction with user-defined functions to calculate a quantity that appears in the input files. Observations to be matched in the regression can be any quantity for which a simulated equivalent value can be produced, and simulated equivalent values are calculated using values that appear in the application model output files and a set of additive and multiplicative functions. Prior, or direct, information on estimated parameters also can be included in the regression. Statistics are calculated and printed for use in (1) diagnosing inadequate data and identifying parameters that probably cannot be estimated; (2) evaluating estimated parameter values; (3) evaluating the model representation of the actual processes; and (4) quantifying the likely uncertainty of model simulated values.

Agency and Office:

International Ground Water Modeling Center of the Colorado School of Mines

and

U.S. Geological Survey

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Model Structure or Mathematical Basis:

The nonlinear regression problem is solved by minimizing a weighted least-squares objective function with respect to the parameter values using a modified Gauss-Newton method. Sensitivities needed for the method are calculated approximately by forward or central differences, and problems and solutions related to this approximation are discussed in the documentation which is included as pdf files in the download.

Model Parameters:

In UCODE, the term ‘parameter’ is reserved for the parameters of the application file that can be estimated by the regression. For UCODE input, see the section below entitled “Input Data Requirements”.

Spatial Scale Employed in the Model:

Governed by the spatial scale of the application model(s).

Temporal Scale Employed in the Model:

Governed by the temporal scale of the application model(s).

Input Data Requirements:

UCODE input includes (1) variables which control the calculation of sensitivities and the regression, (2) commands for executing the application model(s), (3) observation data used to estimate values of defined parameters, (4) information needed to substitute parameter values into application model input files, and (5) information needed to extract simulated values out of application model input files.

Computer Requirements:

UCODE is intended for use on any computer operating system; it consists of algorithms programmed in perl, a freeware language designed for text manipulation, and Fortran90, which efficiently performs numerical calculations. UCODE has been tested extensively on Windows and Unix operating systems.

Model Output:

Primary output is sensitivity of the observations to parameters and the estimated parameters that minimize the objective function. Other output includes statistics that describe how well the application models match the observations using the estimated parameters. Statistics are calculated and printed for use in (1) diagnosing inadequate data and identifying parameters that probably cannot be estimated; (2) evaluating estimated parameter values; (3) evaluating the model representation of the actual processes; and (4) quantifying the likely uncertainty of model simulated values.

Parameter Estimation / Model Calibration:

As described above, this code is a universal inversion tool that can be applied to any other model with text-based input and output, that can be run in batch mode.

Model Testing and Verification:

A test data set is included with the download. Exact comparison have been obtained between UCODE inversions of MODFLOW and MODFLOWP results, and UCODE has been tested on synthetic problems with known solutions.

Model Sensitivity:

UCODE is used to determine sensitivity of other models to defined parameters.

Model Reliability:

UCODE has been tested extensively as defined above and has been found to perform reliably.

Model Application / Case Studies:

UCODE was released one year ago and published applications are not yet common. UCODE is based on the same methods and ideas used to design the USGS computer program MODFLOWP (Hill, 1992), and some of the UCODE code is derived directly from MODFLOWP. Consequently, selected references for applications of MODFLOWP are listed here to assist users with the issues related to applying UCODE. Issues related to weighting of observations, interpretation of results, and appropriate procedures when the regression is not proceeding in an acceptable manner are the same for MODFLOWP and UCODE, and are presented by Hill (1998).

Related references:

The USGS references can be ordered from:

U.S. Geological Survey Books and Open-File Reports Section Box 25425, Mail Stop 517 Federal Center Denver, CO 80225-0425

Anderman, E.R., Hill, M.C., Poeter, E.P., 1994, Two-dimensional advective transport in nonlinear regression - - Sensitivities and uncertainty of plume-front observations: in Warner, J. and others, eds, 1994 Ground Water Conference, Fort Collins, CO, Proceedings, p. 55-62

Anderman, E.R., Hill, M.C., Poeter, E.P., 1996, Two-dimensional advective transport in ground-water flow parameter estimation: Ground Water, 34(6): 1001-1009.

Cooley, R.L. and Naff, R.L., 1990, Regression modeling of ground-water flow: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter B4, 232 p.

Christensen, Steen, 1997, On the strategy of estimating regional-scale transmissivity fields: Ground Water, 35(1):131-139

Christensen, Steen and Cooley, R.L., in press, Simultaneous confidence intervals for a steady-state leaky aquifer groundwater flow model: Advances in Water Resources Special Issue on Model Calibration and Reliability Analysis.

D'Agnese, F.A. Faunt, C.C., Turner, A.K., and Hill, M.C., 1998, Hydrogeologic evaluation and numerical simulation of the Death Valley Regional ground-water flow system, Nevada and California: U.S. Geological Survey Water-Resources Investigation Report 96-4300, 124p.

D'Agnese, F.A. Faunt, C.C. Hill, M.C., and Turner, A.K., in press, Death Valley regional ground-water flow model calibration using optimal parameter estimation methods and geoscientific information systems: Advances in Water Resources Special Issue on Model Calibration and Reliability Analysis.

Hill, M.C., 1992, A computer program (MODFLOWP) for estimating parameters of a transient, three-dimensional, ground-water flow model using nonlinear regression: U.S. Geological Survey Open-File Report 91-484, 358 p.

Hill, M.C., 1994, Five computer programs for testing weighted residuals and calculating linear confidence and predictions intervals on results from the ground-water parameter-estimation computer program MODFLOWP: U.S. Geological Survey Open-File Report 93-381, 81p.

Hill, M.C., Cooley, R.L., and Pollock, D.W., 1998, A controlled experiment in ground-water flow model calibration: Ground Water, vol. 36, no. 3, p.520-535.

Holtschlag, D.J., Luukkonen, C.L., and Nicholas, J.R., 1996, Simulation of ground-water flow in the Saginaw aquifer, Clinton, Eaton, and Ingham Counties, Michigan: U.S. Geological Survey Water Supply Paper 2480, 49p.

Poeter, E.P. and Hill, M.C., 1997, Inverse modeling, A necessary next step in ground-water modeling: Ground Water, 35(2):250-260.

Poeter, E.P. and McKenna, S.A., 1995, Reducing uncertainty associated with ground-water flow and transport predictions: Ground Water, 22(6): 899-904.

Tiedeman, C.R., Goode, D.J., and Hsieh, P.A., in press, Numerical simulation of ground-water flow through glacial deposits and crystalline bedrock in the Mirror lake area, Grafton Coundty, Ne Hampshire: U.S. Geological Survey Professional Paper 1572.

Tiedeman, Claire and Gorelick, S.M., 1993,Analysis of uncertainty in optimal groundwater contaminant capture design: Water Resources Research, v. 29, no. 7, p.2139-2153

Yager, R.M., 1993, Simulated three-dimensional ground-water flow in the Lockport Group, a fractured dolomite aquifer near Niagara Falls, New York: U.S. Geological Survey Water-Resources Investigations Report 92-4189, 43 p.

Documentation:

Poeter, E.P. and M.C. Hill, 1998, Documentation of UCODE: A computer Code for Universal Inverse Modeling, U.S. Geological Survey Water-Resources Investigations Report 98-4080, 116 pp.

Hill, M.C., 1998, Methods and guidelines for effective model calibration: U.S. Geological Survey, Water-Resources Investigations Report 98-4005.

These are included as a pdf files in the download.

Other Comments: