eMOD : a MATLAB application for MODFLOW-based groundwater flow and solute transport models

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ABSTRACT

eMOD, or elementary MODFLOW, is a freeware software package to prepare input files and handle output for the groundwater flow model MODFLOW2005, the density dependent multi-species solute transport model SEAWAT and the reactive transport model PHT3D.

INTRODUCTION

eMOD (Vandenbohede, 2013) provides a no-nonsense approach to simulations. *'Elementary'* means that the interface to work with MODFLOW based simulations is simple and easy to use and learn. It also means that input not essential to the simulation is kept to a minimum. The user works directly with the different packages which implies that there is no handling of data which is not controlled by the user. Therefore models can be made in a flexible way and can be easily modified to experiment with different conceptual models or parameter combination. The aim of eMOD is to apply simulations straightforward to gain insight in a groundwater system, without losing oneself unnecessary in a complex user interface.
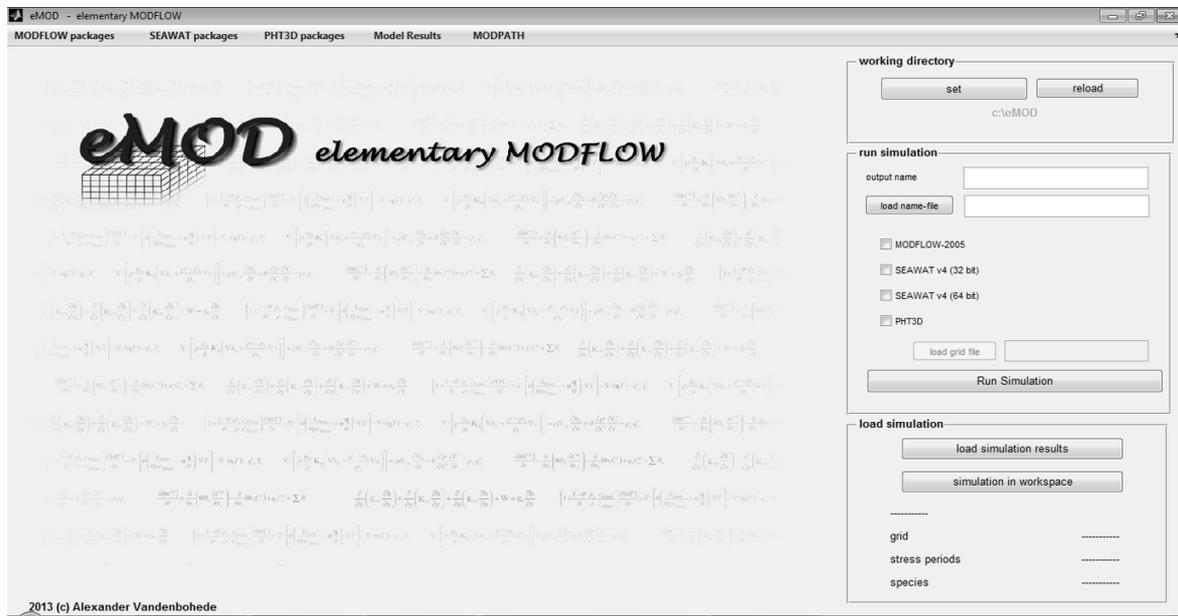

Figure 1. Main window of eMOD.

Possible disadvantage of this approach is that no GIS system is provided to define simulation input or to visualize output. However, model output can be easily exported in a format which can be loaded in GIS software. Also, the input can be made with the assistance of GIS software using xls(x)-files as a link between GIS and eMOD.

INPUT AND OUTPUT

The current eMOD version supports following MODFLOW2005 (Harbaugh, 2005) packages: discretization (dis), basic (bas), block centered flow (bcf), layer property flow (lpf), horizontal barrier flow (hfb), constant head boundary (chd), recharge (rch), well (wel), evapotranspiration (evt), multi-node well (mnw1 and mnw2), river (riv), drainage (drn), lake (lak), streamflow-routing (sfr), unsaturated-zone flow (ufz), general head boundary (ghb), strongly implicit procedure (sip), preconditioned conjugate-gradient (pcg) and, direct solver (de4) package. It supports following MT3D-MS packages: basic transport (btn), advection (adv), dispersion (dsp), sink-source mixing (ssm) and, generalized conjugate-gradient (gcg) package. It supports following SEAWAT (Langevin et al., 2007) packages: variable-density flow (vdf) and viscosity (vsc) package. It supports following PHT3D (Prommer and Post, 2010) packages: interface package and database file.

Input to prepare these packages is via interactive GUIs (figure 2a) combined with excel spread sheets (xls(x)-files). Hereby, for instance, MATLAB, PYTHON or a GIS program can be used to make the spread sheets in a flexible way in case the input becomes large or complicated. A special package is included to prepare input for radial flow cases (i.e. aquifer tests, upconing, aquifer storage and recovery) which automatically recalculates relevant parameters from a radial geometry to the Cartesian geometry used by MODFLOW (Langevin, 2008; Louwyck et al., 2012; Vandenbohede et al., 2014; Wallis et al., 2013).
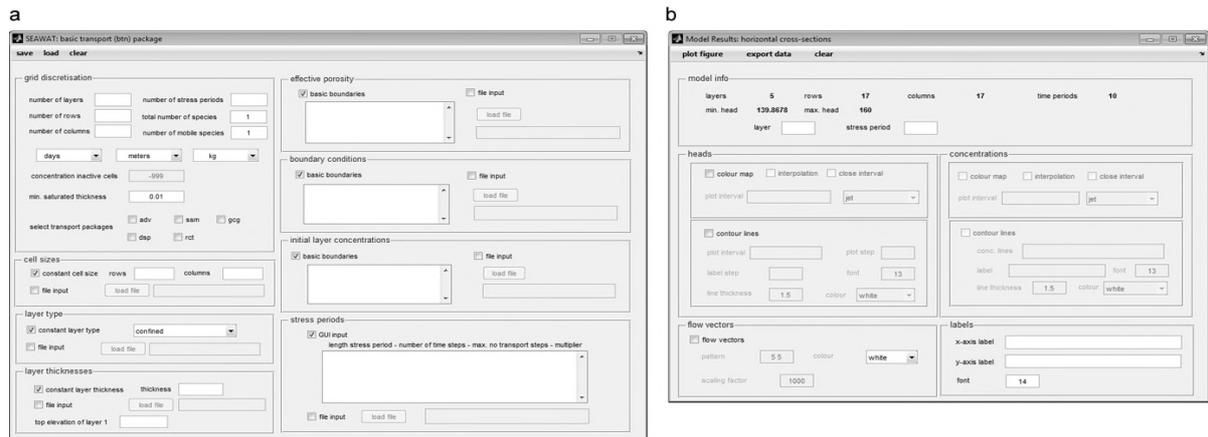

Figure 2. Example of an input GUI, here for the btn package (a) and an example of a GUI to plot simulation output, here to plot horizontal cross-sections (b).

Output can be visualized with cross-sections (Figure 2b), movies and graphs showing aquifer heads, concentrations and/or flow vectors. Pathlines and capture zones can be calculated using MODPATH and be visualized in a number of ways.

AVAILABILITY

eMOD is programmed as a MATLAB tool but can also be used as a stand-alone application. The advantage of using eMOD as a MATLAB application is that full use of the functionalities of MATLAB can be made. The advantage of using eMOD as a stand-alone application is, of course, that MATLAB is not needed.

eMOD is freeware and is available for download at the repository on *https://github.com/eMOD/* where you find a folder containing a manual and the software.

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