

Ecolego - a toolbox for radioecological risk assessment

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Abstract. Ecolego is a MATLAB[®] toolbox for modelling dynamic systems and to perform risk assessments using model simulations. The toolbox supports linear and non-linear systems, modelled in continuous time, sampled time, or a hybrid of the two. The Graphical User Interface of Ecolego facilitates the transition from a conceptual model, represented with an interaction matrix, to a mathematical model implemented in Simulink[®]. Ecolego includes routines for probabilistic simulations, correlation between parameters, sensitivity analyses, uncertainty analyses and parameter optimisation. Even though the toolbox can be used to simulate any species and dynamic system, it has been specially designed to fulfil specific needs in the field of radioecological risk assessment. Ecolego includes a library with radionuclide data and it supports automatic consideration of radionuclide decay chains. This paper provides an overview of the functioning and features of Ecolego.

1. Introduction

Radioecological risk assessment often involves simulations with models of the radionuclide transfer in the environment and with dosimetric models to estimate the exposure of man and biota to ionising radiation. There exist several commercial software packages [1][2], which can be used for model implementation. Their capabilities are, however, limited to linear models (Ordinary Differential Equations – ODE) and cannot be fully customised, since their code is hidden to the users. Besides, they have a limited number of numerical solvers, which are not universally applicable and in some cases outdated. An alternative is to use Simulink, which is a MATLAB [3] toolbox to model, simulate and analyse dynamical systems. Simulink is designed to be universal, in the sense that models are built at the “atomic level”, i.e. the user defines each elementary block and signal. This property, together with its full integration with MATLAB, makes it possible to implement in Simulink practically any type of model and simulation method. A drawback, though, is that substantial experience and effort is required to implement a model and to take advantage of all available capabilities. Moreover, users not familiar with Simulink may have difficulties to understand and run models implemented by others. In an effort to overcome these negative aspects, whilst keeping the advantages, we initiated a project dedicated to development of an interface, which we call Ecolego, to facilitate the implementation of radioecological models and to perform radioecological risk assessments in a MATLAB/Simulink environment.

2. Structure and functioning

The main components of Ecolego and their interactions are shown in *Fig. 1*. The Graphical User Interface (GUI) allows the user, who does not need to be familiar with MATLAB/Simulink, to define the conceptual model, transfer functions, initial conditions, model parameters, simulation settings, etc (see epigraph 3). The MATLAB code processes this information and prepares the inputs needed by the Simulink code. The Simulink code generates the Simulink model using Simulink construction commands, for instance **add_block** adds a new block to the model, **set_param** is used to specify the block properties, **add_line** is used to connect two blocks, etc.

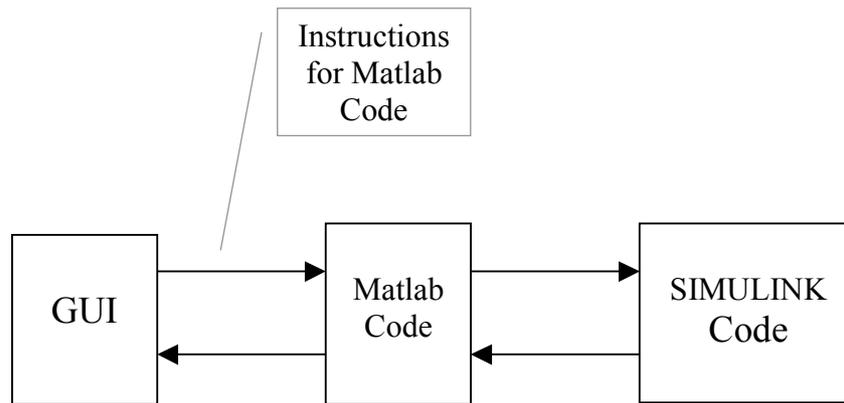


FIG. 1. Main components of Ecolego and their interactions

The simulations are controlled by the MATLAB code, which receives the simulation results from the Simulink code and passes them to the GUI. Note that the more blocks and connections are added, the more complicated becomes the Simulink model. However, since the construction process is fully done by the Simulink code (about 800 lines of code were needed to cover all possible situations in a generic way), the user will always deal with a simple system.

2.1. Advantages of the MATLAB/Simulink environment

The Ecolego implementation in a MATLAB environment has the following advantages:

- The whole code is open and not compiled, since MATLAB is an interpret-type programming language, which allows the user to add new functionalities and introduce modifications.
- The user has full direct access to all functions, numerical solvers, toolboxes and graphical capabilities of MATLAB.
- Codes written in either MATLAB or other programming language can be used directly in Ecolego. This functionality increases substantially the scope of application of Ecolego well outside systems that can be represented with ODE. For instance, a geosphere transport model based on partial differential equations can be implemented as a MATLAB function and fully integrated with a biosphere compartment model, a near field model, etc.
- MATLAB and Simulink software have been widely used by the scientific community for a long time and are continuously upgraded. This is an advantage for the quality assurance of Ecolego and provides for a constant improvement.
- The code is platform independent and can run on Windows, Macintosh and Linux computers.

3. Modelling with Ecolego

The GUI includes a routine for representation of the conceptual model with the help of interaction matrices [4] as illustrated in Fig. 2, which shows the same model represented with a traditional flow diagram and with an interaction matrix. Each matrix element is treated as an object, which could also be a matrix, i.e. a sub-model. This facilitates using a top-down approach, which might be especially useful when modelling complex systems and to create hierarchical models.

A special routine has been implemented to handle several radionuclides in the same model. Basically, the user has only to select the radionuclides, and radionuclide decay chains, that will be considered in the model, and Ecolego will scale accordingly the signals dimensions, make corrections for decay and ingrowths, etc.

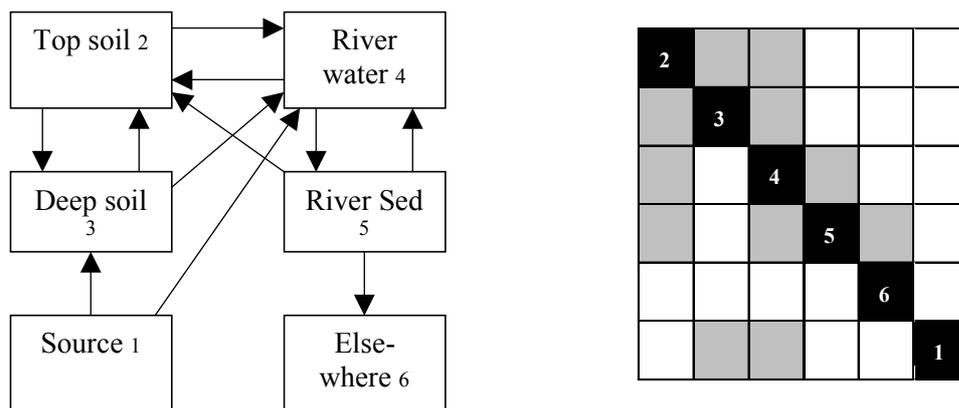


FIG. 2. Conceptual representation of the model used in the comparison exercise PSCoin [5] using a traditional flow diagram (left) and an interaction matrix (right). The diagonal elements correspond to the components of the system and the off-diagonal elements to their interactions. The matrix should be read clockwise

3.1. Towards a “LEGO” functionality

One important element in our development strategy has been to give to Ecolego what we call “LEGO” functionality. By this we mean that the user will be able to build a model in a way that resembles playing with pieces of LEGO. To achieve this we are integrating in Ecolego a database of objects. When a model is created in Ecolego, the model itself and all his elements (diagonal and off-diagonal elements in the matrix – see Fig. 2) can be added to the database. The elements in the database can be afterwards combined with each other to create new models. When doing this they acquire new properties and in this way the database can be continuously enlarged. Parameter names and values, transfer functions, probability distributions, etc can also easily be added to the database. Models created with other applications can also be built-in the database.

4. Performing simulations

The Simulink model created by Ecolego can be integrated using any of the numerical solvers available in MATLAB. Ecolego currently supports the basic simulation routines needed for conducting a risk analysis. Probabilistic simulations can be carried out using an engine for Monte Carlo or Latin Hypercube sampling, with the option of taking into consideration binary and multiple correlations [5] between parameters. It is also possible to conduct sensitivity analyses [6] and parameter optimisation [7]. The results of the simulations can be viewed using the powerful MATLAB graphic capabilities and/or directly exported to excel.

5. Benchmarking and applications

Even though Ecolego uses well known and quality assured MATLAB/Simulink routines, we have nevertheless conducted a series of benchmark calculations for quality control of the whole toolbox. For instance we implemented in Ecolego the model used in the IAEA intercomparison exercise PS Coin (shown in Fig. 2) and did the specified calculations [5]. The results of the deterministic and probabilistic calculations were practically identical for all radionuclides, including those for radionuclide chains. The suit of forest models FORESTLAND [8], originally implemented in Stella [1], was set up in Ecolego and comparisons were made for several simulation cases using the same numerical solver. The results again were practically identical. We have also obtained satisfactory results in comparisons against Model Maker [2] using the biosphere models described in [9] and against Amber [10] using the near field and geosphere models described in [11].

Ecolego has been used within the EC projects FASSET [12] and BORIS [13] for implementation and development of models. Following our strategy of giving to the toolbox “LEGO” functionality, we are implementing in Ecolego “state of the art” models available in the literature for different radionuclides and ecosystems of interest. We have adopted the classification of ecosystems used in FASSET comprising forests, seminatural ecosystems, agricultural lands, wetlands, fresh water and marine ecosystems. Hitherto models for forest, seminatural and marine ecosystems have been implemented.

ACKNOWLEDGEMENTS

The Swedish and Norwegian Radiation Protection Authorities have sponsored the development of Ecolego. We would like to thank Leif Moberg and Justin Brown for encouraging us and for supporting this project.

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