Coupling easily numerical models using the VSoil modelling platform
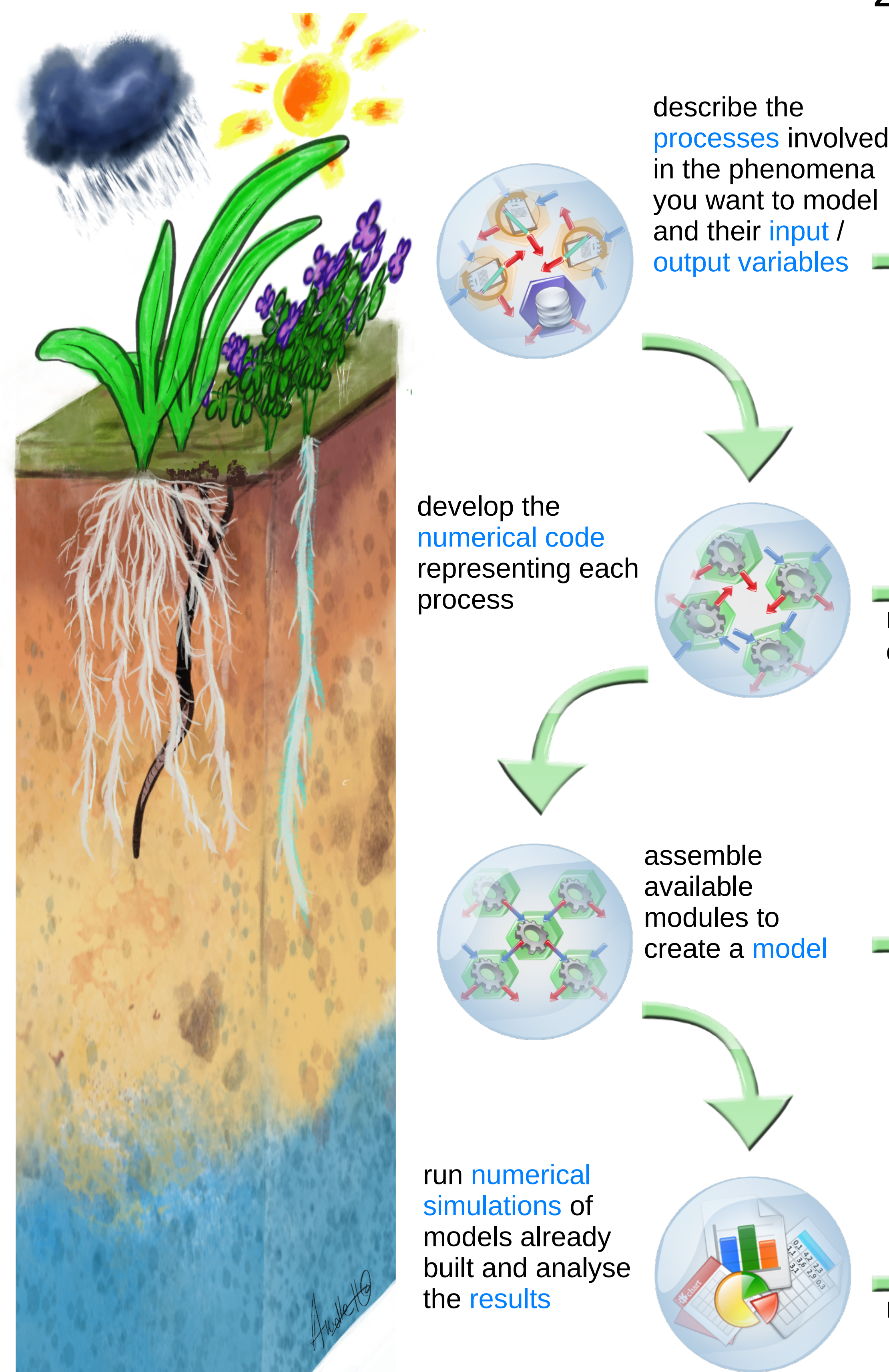
Nicolas Beudez[1], Nicolas Moitrier[1], Nathalie Moitrier[1], Cédric Nouguier[1], Stéphane Ruy[1], François Lafolie[1]

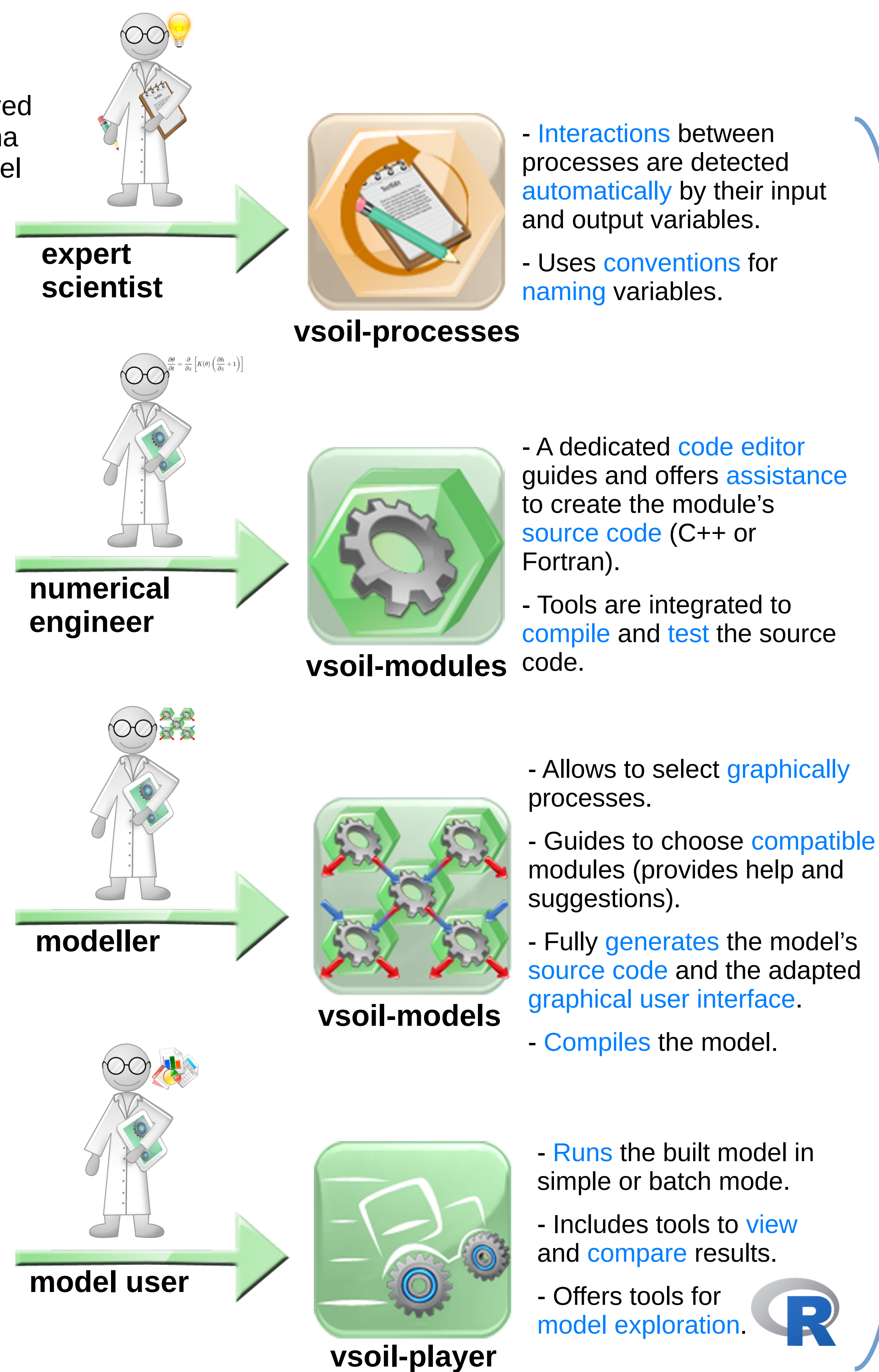[1]INRAE, Avignon Université, UMR EMMAH, F-84914, Avignon, France

1. Scientific needs

To provide a detailed representation of soil functioning, it is necessary to couple a large number of models that represent the various processes taking place within it.

describe the processes involved in the phenomena you want to model and their input / output variables.

expert scientist

vsoil-processes

- Interactions between processes are detected automatically by their input and output variables.
- Uses conventions for naming variables.

develop the numerical code representing each process

numerical engineer

vsoil-modules

- A dedicated code editor guides and offers assistance to create the module's source code (C++ or Fortran).
- Tools are integrated to compile and test the source code.

assemble available modules to create a model

modeller

vsoil-models

- Allows to select graphically processes.
- Guides to choose compatible modules (provides help and suggestions).
- Fully generates the model's source code and the adapted graphical user interface.
- Compiles the model.

run numerical simulations of models already built and analyse the results

model user

vsoil-player

- Runs the built model in simple or batch mode.
- Includes tools to view and compare results.
- Offers tools for model exploration.

YOU CAN START AT ANY STEP

Informations, contact and support

You can access the VSoil's website here:

SCAN ME

You can contact us here: vsoil@inrae.fr

Support:
- VSoil team: 1 researcher, 3 software engineers and 1 scientific computing engineer;
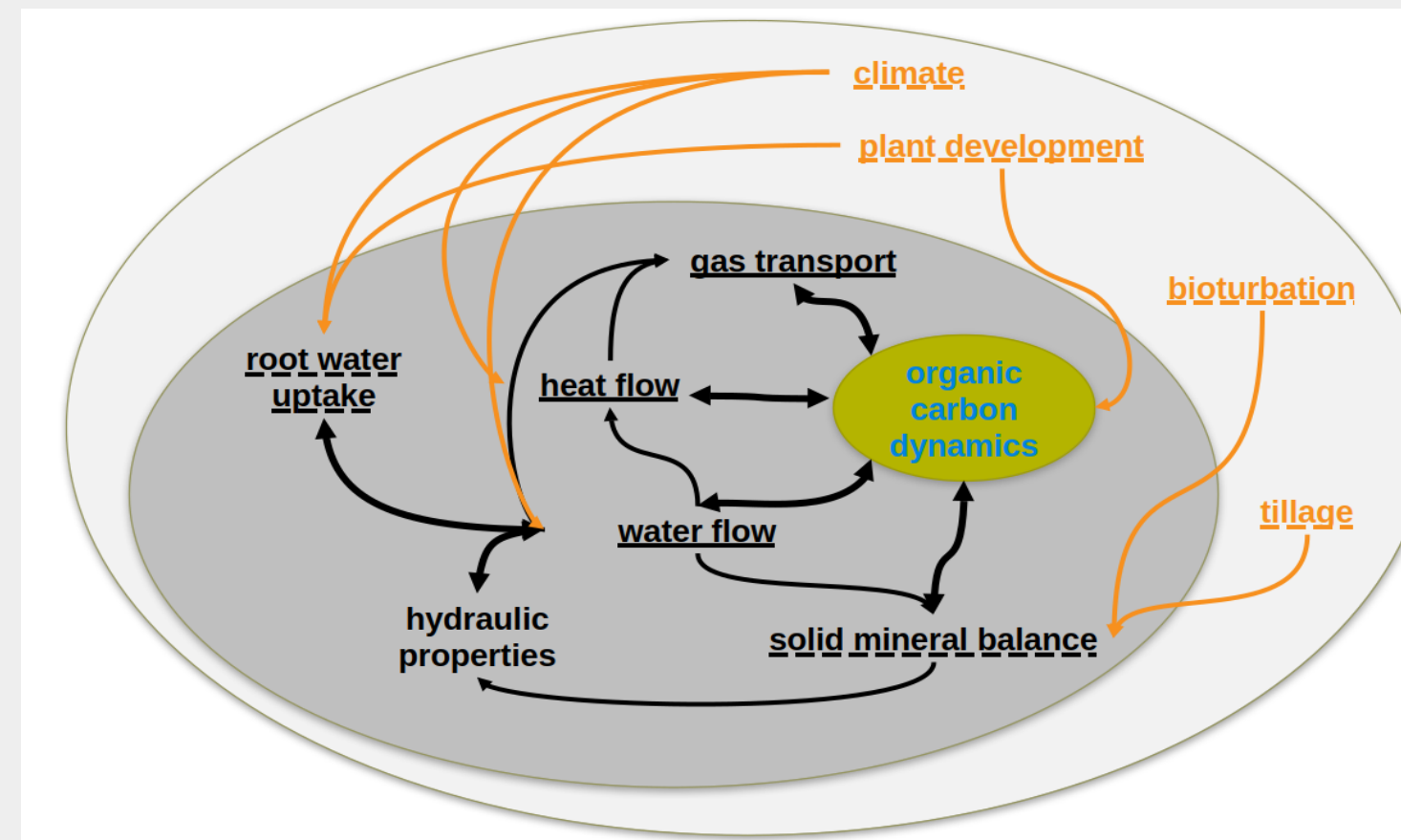- reference scientists for the models.

Acknowledgements

2. The VSoil collaborative platform

An open-source platform under Apache 2 licence designed to aid the development of numerical models at the soil profile scale describing physical, chemical and biological processes in soil and its interactions with climate, plants and anthropic activities.

2.1 The VSoil software suite

2.2 Particular features

- Open library: currently ~700 variables, ~50 processes, ~150 modules and ~20 models. Examples of processes: water, heat and gas transfers, organic matter dynamics, solute transport, evapotranspiration...

- Automatic generation of:
  - model's source code and graphical user interface;
  - output files;
  - R scripts for sensitivity analysis and parameter estimation.

- Remote computing on servers or clusters.

- 'Stop and resume' functionality (for example to update weather data during simulation).

- VSoil models can be integrated into third-party models / platforms.

- A collaborative tool: exchanges between users (export / import system) + capitalisation by the VSoil team (sharing with the community).

3. Some use cases

3.1 Modelling pedogenesis processes

OC_VGEN (Keyvanshokouhi et al., 2019): model developed in VSoil to simulate the evolution of soil properties at the century scale in a vertical soil profile.

Several processes are represented into dedicated modules adapted from the **SoilGen** (Finke and Hudson, 2008) and **PASTIS** (Lafolie, 1991 and Findeling et al., 2007) models.

_Processes involved in the OC_VGEN model (H. Chaif)_

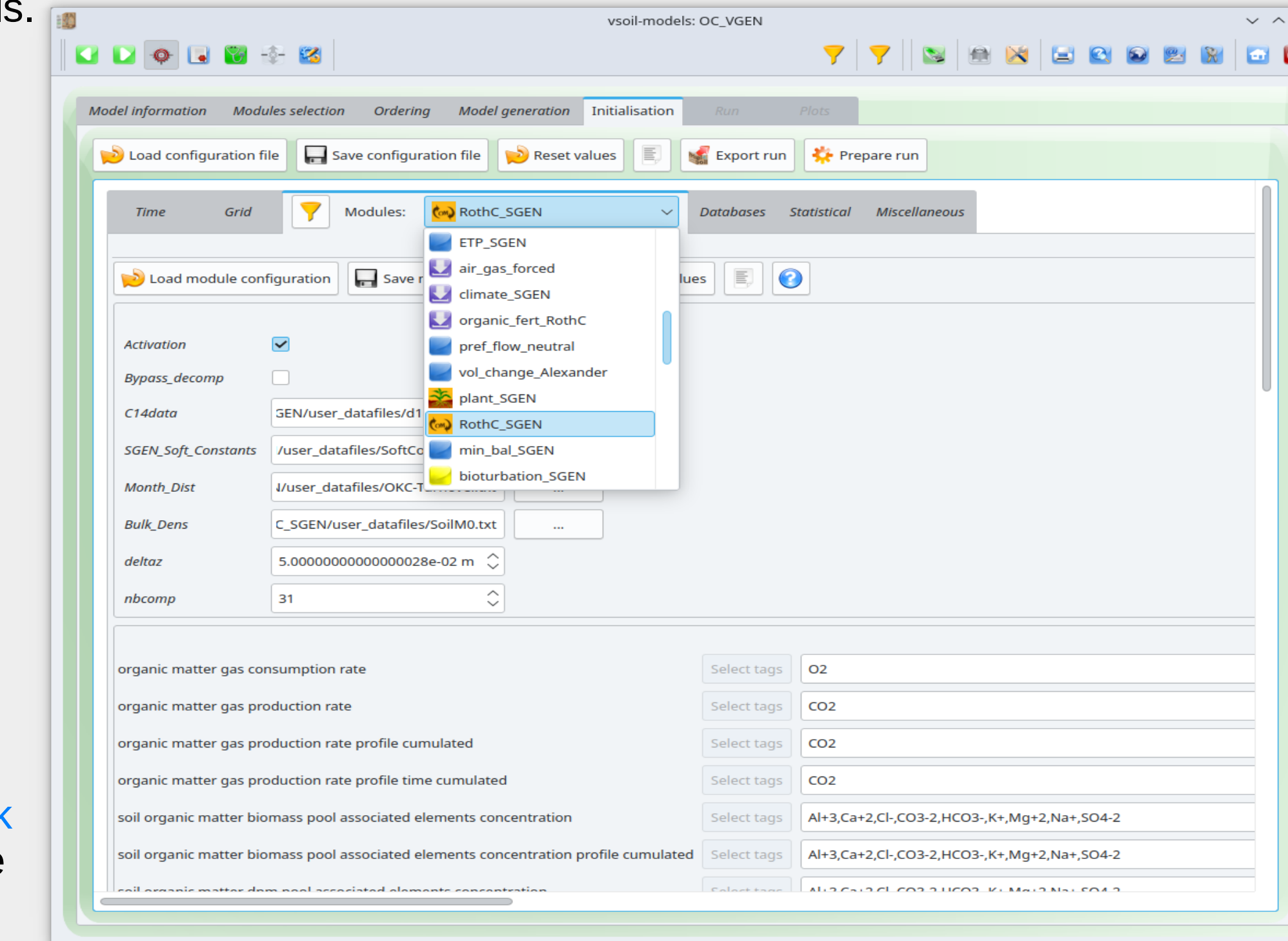Introduced time-adaptative meshing in VSoil: → save computing time on century-scale simulations

Recent improvement of **OC_VGEN** model:

add a module to take account of volume change of soil over time (Chaif et al., 2025) → better prediction of bulk density evolution at the century scale

Automatically generated GUI for configuring the model (vsoil-models)

3.2 Building a model for predicting the risk of rutting in forest soils

Context: forestry machine traffic is one of the main causes of physical degradation of forest soils and, consequently, of forest stands.

Forestry machinery travels on dedicated tracks known as skid trails, whose practicability must be maintained over the long-term.

Ruts in the Grand-Pays national forest (Meuse, France) – March 2021

Forestry machinery traffic test - 2018

Development of a climate service prototype for real-time prediction of the water status of skid trails over the next 14 days:

observed and forecast weather data (ECMWF) + model to simulate the degree of water saturation of skid trails + ask minimum information to forestry operators = predicting the risk of rutting

Steps:

1) Building the model within VSoil:

1D mechanistic model of the soil-litter-tree-atmosphere system to simulate water transfer in an undisturbed and compacted forest soil (Martin et al., 2024).

+

module for calculating soil practicability indices

2) Sensitivity analysis to identify most important model's parameters on the number of practicable days predicted: use of R packages through VSoil.
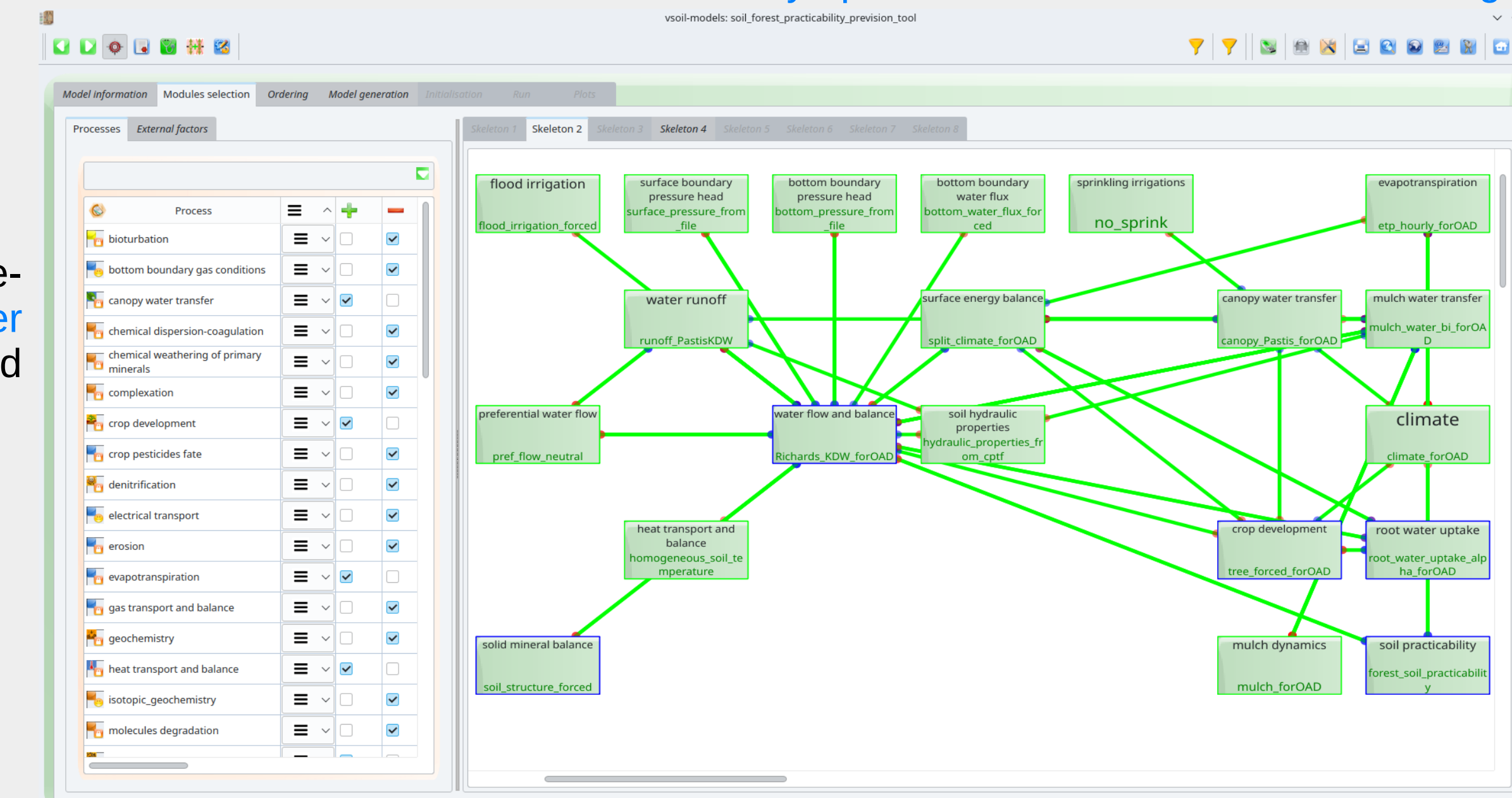
Graphical selection of processes and associated modules (vsoil-models)

4. Perspectives

- New models available soon (ex: hydro-geophysics).

- Development of 3D modelling to take better account of soil heterogeneity.

- Access to free forecast and observed weather data to feed models.

References

Lafolie (1991), DOI: 10.1007/bf01051129
Findeling et al. (2007), DOI: 10.1111/j.1365-2389.2006.00826.x
Finke and Hudson (2008), DOI: 10.1016/j.geoderma.2008.01.017
Keyvanshokouhi et al. (2019), DOI: 10.1016/j.scitotenv.2018.10.236
Martin et al. (2024), DOI: 10.1186/s13595-024-01265-4
Chaif et al. (2025), DOI: 10.1016/j.geoderma.2025.117228