Presentation of the Virtual Soil (VSoil) project

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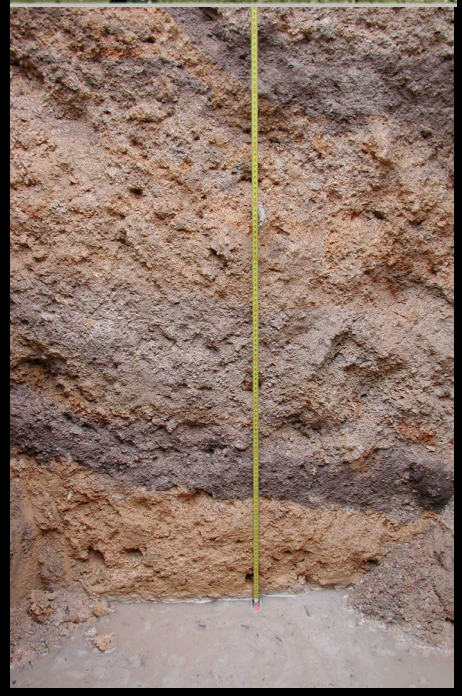
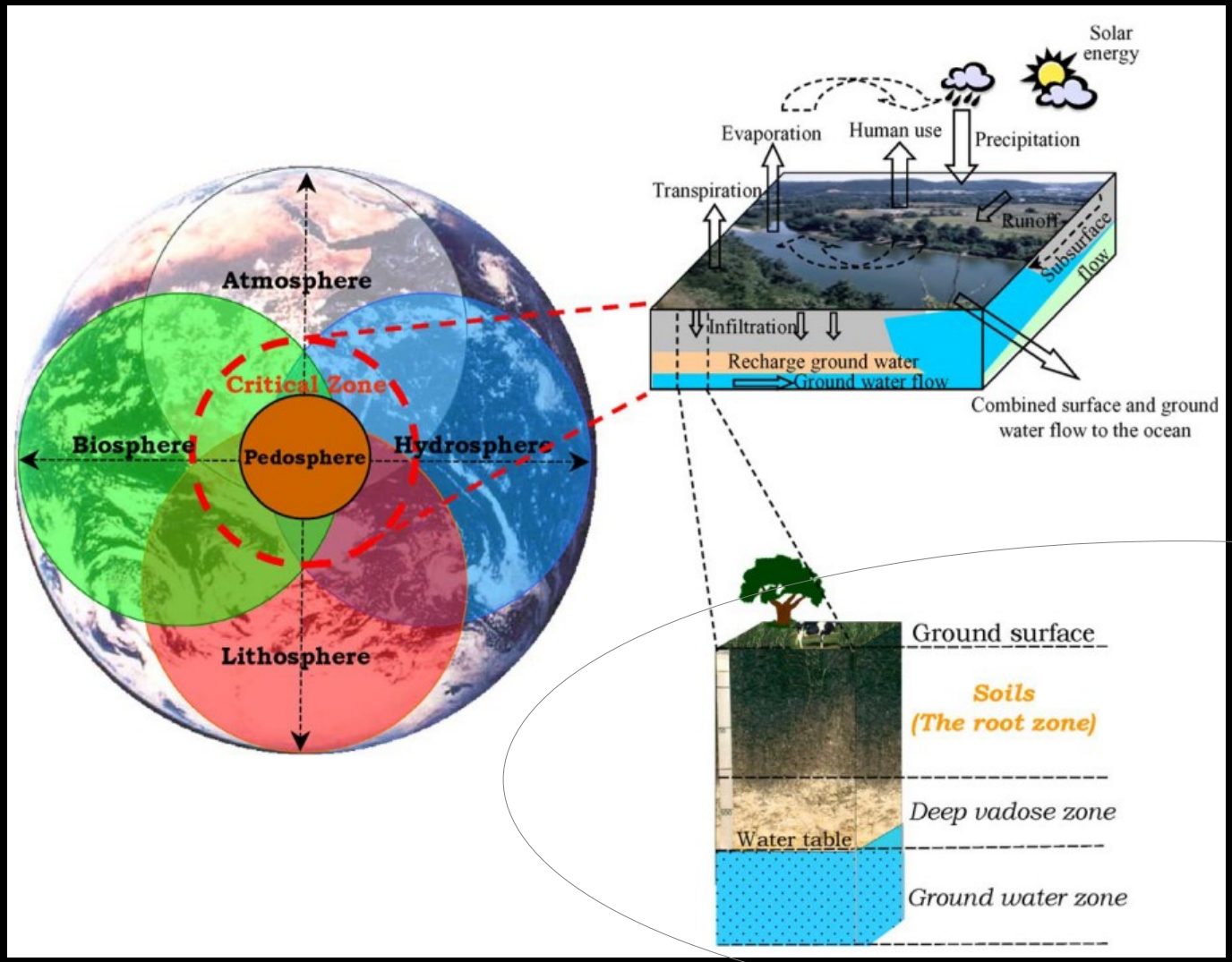
EMMAH unit, Avignon, 4 mai 2022



Context: soil

Climate change.
Changement of use.
Evolution ?



The soil is at the heart of the critical zone of exchange of water and solutes, gases, solids, energy and organisms that extends from the upper canopy to the satured soil zone.

Pedon

- Local scale (a few m²).
- Soil profile from the surface to the groundwater or bedrock including the root exploration zone.

Modelling requirements

Survey conducted between 2006 and 2008 within the Environment and Agronomy department of INRA

➡ Develop models that **couple mechanisms**:

- at different scales of time and space

- of different natures

➡ key point to understand the functioning and predict the evolution of soils

➡ Models should be developed **easily** et **quickly**: use what is available and / or develop new parts

➡ The development of new models should be accessible to all: **coding reduced as much as possible**

Technical barriers

Difficulties in appropriating the **modelling**:

chain: experiments → model → computer code

➡ **need for support**

Different computer languages (Fortran, C, C++, Java, Python, …) for programming whose lack of standards **restrains the coupling** of existing models

Lack of assistance and support for computer programming of simple and complex models

➡ Expectations ⇒ to have a structure that:
- allows to host and share models
- facilitates the development of new models
- allows to analyse the properties of these models

Objectives

Create a structure to:

- **facilitate** the use of existing tools
- **reuse** and **capitalise** on the existing
- have a **modular modelling** approach
- accept **several representations** of a phenomenon
- **manage the coupling** of mechanisms
- **assist** in the development of new modelling approaches
- **facilitate interactions** between « modellers » and « experimenters »
- **facilitate communication** between scientists from different fields
- **share** and **make** innovations **« immediately » usable** for all users of the structure

The VSoil software platform

VSoil is a **modelling software platform** supported by the INRAE Agroecosystems department and hosted in EMMAH unit on the Avignon site (developed since 2009)

It is a tool to **assist in the development of numerical models** describing the **physical, chemical and biological processes** of the soil in interaction with climate, plants and human actions

VSoil **facilitates the coupling** between these processes and makes it possible to develop complex models from the **assembly of existing or new source codes**

Space for **animation** and **scientific collaboration**

Basic concepts

The **processes** that take place in the soil can be « described » and knowledge can be shared

Several representations of a process are possible through **modules**

A **model** is an assembly of modules

The modeller / user must be able to **concentrate on his core business**:

- making bricks (the modules)
- assembling the bricks
- analysing the results

➡ modeller / user should be **relieved** of all tasks that are not its speciality

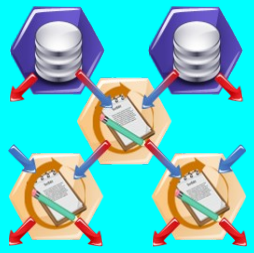
Architecture

From concepts...

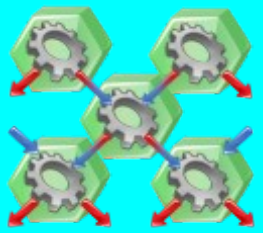
Processes

...encoded in modules,

...form squeletons,



...to create models



...and run simulations

vsoil-processes

vsoil-modules

vsoil-models

vsoil-player

...to softwares

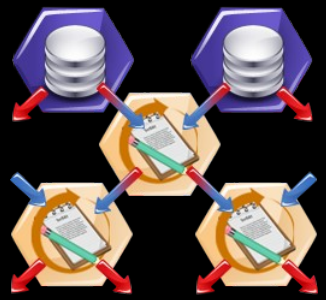
The VSoil software components

1) vsoil-processes :

Phenomena are called **processes**

Some processes are **external**

Interactions between processes are detected using **inputs** and **outputs**



Processes with their inputs and outputs produce graphs: **skeletons**

demonstration !

vsoil-processes

Open lists of variables and processes

Guide for naming variables

Tool for exploring content

Automatic creation of skeletons

Provide information for coding and assembly of modules

The VSoil software components

2) vsoil-modules :

A **module** corresponds to a modelling, a numerical method, ...

It is a computer code (Fortran, C++)

A module is linked to a process

Several modules may be available for a process

A module uses some of the inputs of its process and must produce at least one output

vsoil-modules

Parameters

Coding assistance

Compilation

Tests

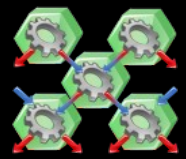
Graphs

Non-invasive (standardised languages)

demonstration !

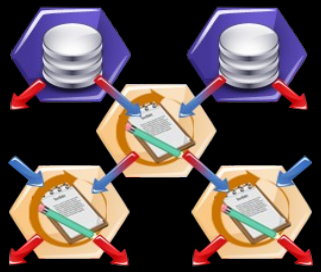
The VSoil software components

3) vsoil-models :

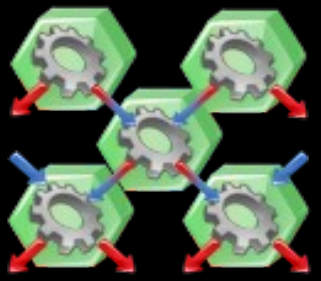


For each process...

… a module is selected



A **model** is based on a skeleton



A **model** is an ordered set of modules

vsoil-models

Module selection

Generation of the main

Generation of the GUI

Execution

Visualization

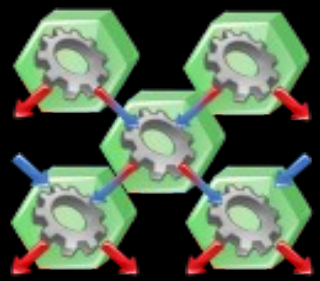
Backup

Modification

demonstration !

The VSoil software components

4) vsoil-player :



A model already built

Simulations, visualisation of results, ...

vsoil-player

Use available models

Run simulations

Archive simulations

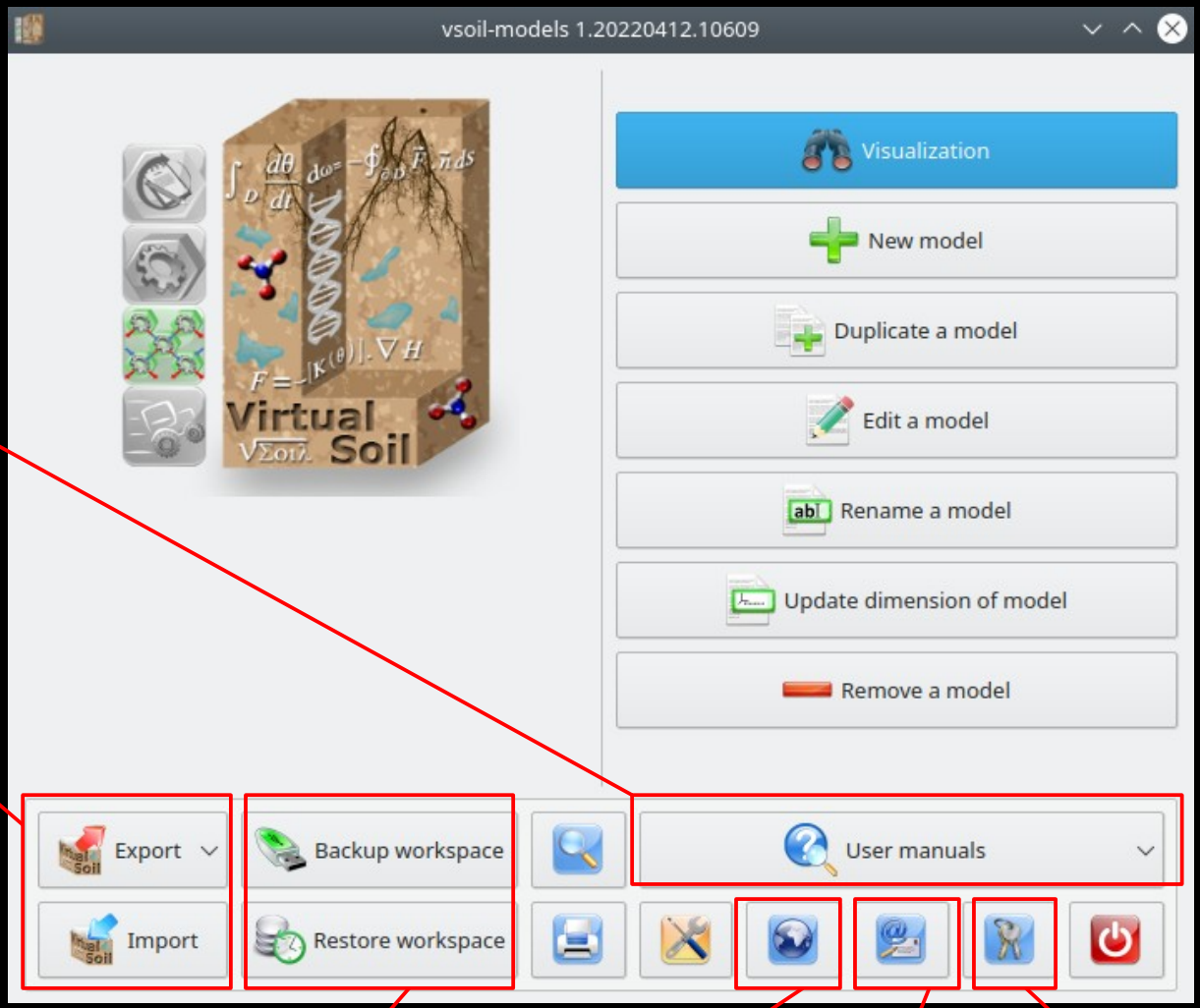
View saved results

Compare simulation results

Perform sensitivity analysis and parameter estimation

demonstration !

A collaborative tool



online documentations (softwares and tutorials)

exchange of « user » objects

backup and restoration

access to the website

contact and support

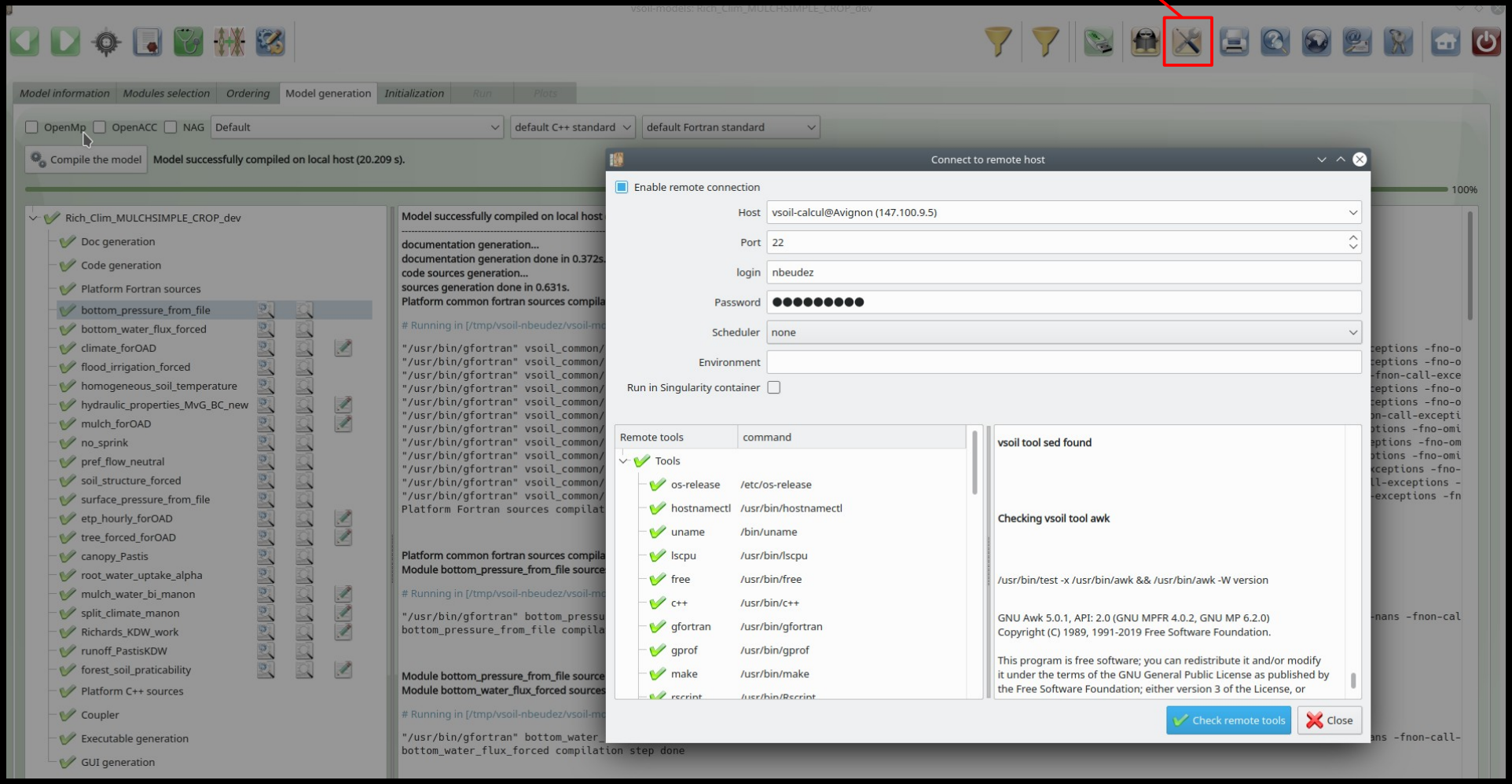
licence and charter

Advantages of VSoil

1) Ability to **run calculations** on **remote** servers:

- « vsoil-calcul » Linux server : Ubuntu 20.04, 56 cores, RAM 92 Go
- compatible clusters

activation of remote connection



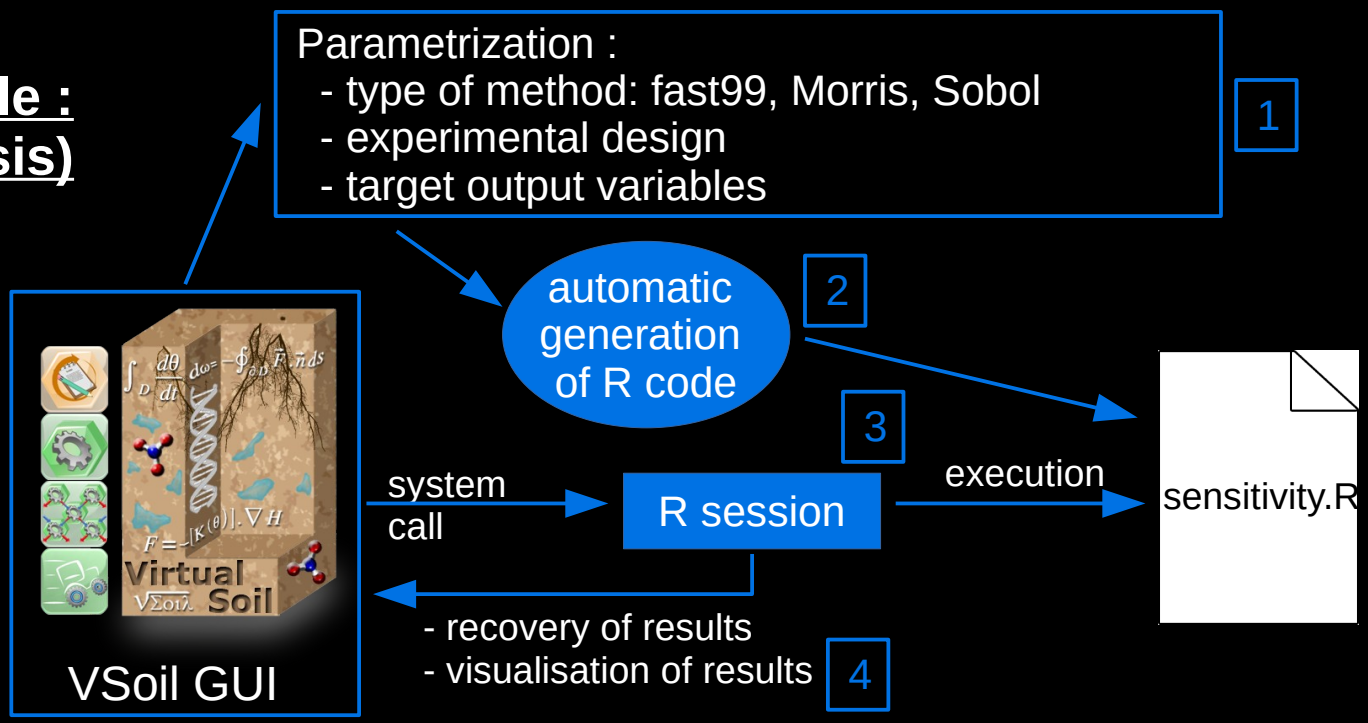
Advantages of VSoil

2) **Model exploration** tools: VSoil models interfaced to dedicated **R packages**

⇒ several methods of **sensitivity analysis**: fast99, Morris, Sobol

⇒ different algorithms for **parameter estimation**:
- Levenberg-Marquardt
- SCE-UA (Shuffle Complex Evolution – Uncertainty Analysis)
- DREAM (Differential Evolution Adaptative Metropolis)
- DREAMzs (Differential Evolution Adaptative Metropolis)

Scenario (example : sensitivity analysis)



Advantages of VSoil

3) Connections to **databases**

web-services

agro-climatic databases
(Climatik: Agroclim unit, Avignon)

soil databases (ACBB SOERE)

SOERE: Long-term Observation and Experimentation System for Environmental Research (« Système d'Observation et d'Expérimentation sur le long terme pour la Recherche en Environnement »)

ACBB: Agro-ecosytem, Bio-geochemical Cycle and Biodiversity (« Agro-écosystème, Cycle Bio-géochimique et Biodiversité »)

Resources

Website: https://www6.inrae.fr/vsoil/

news

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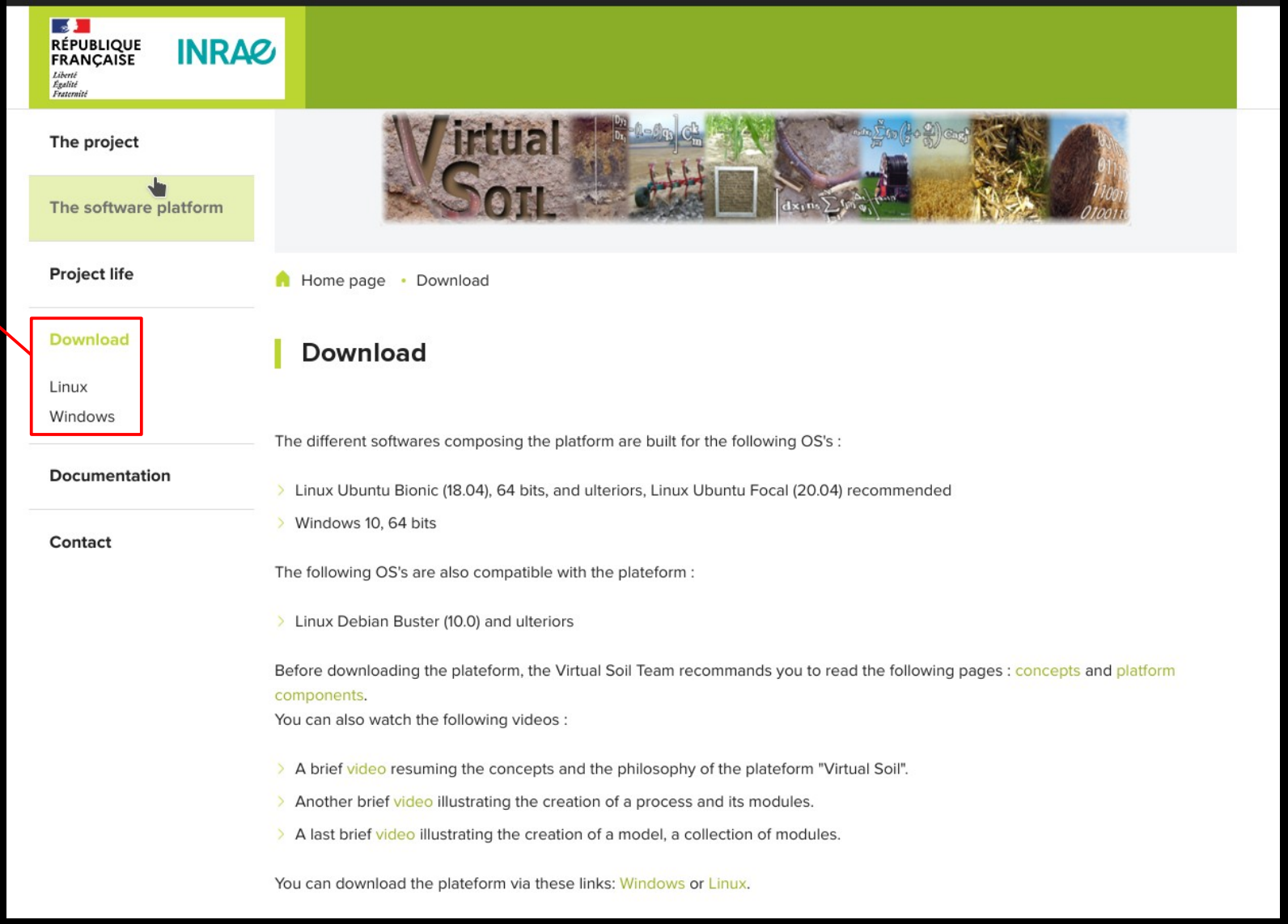
download



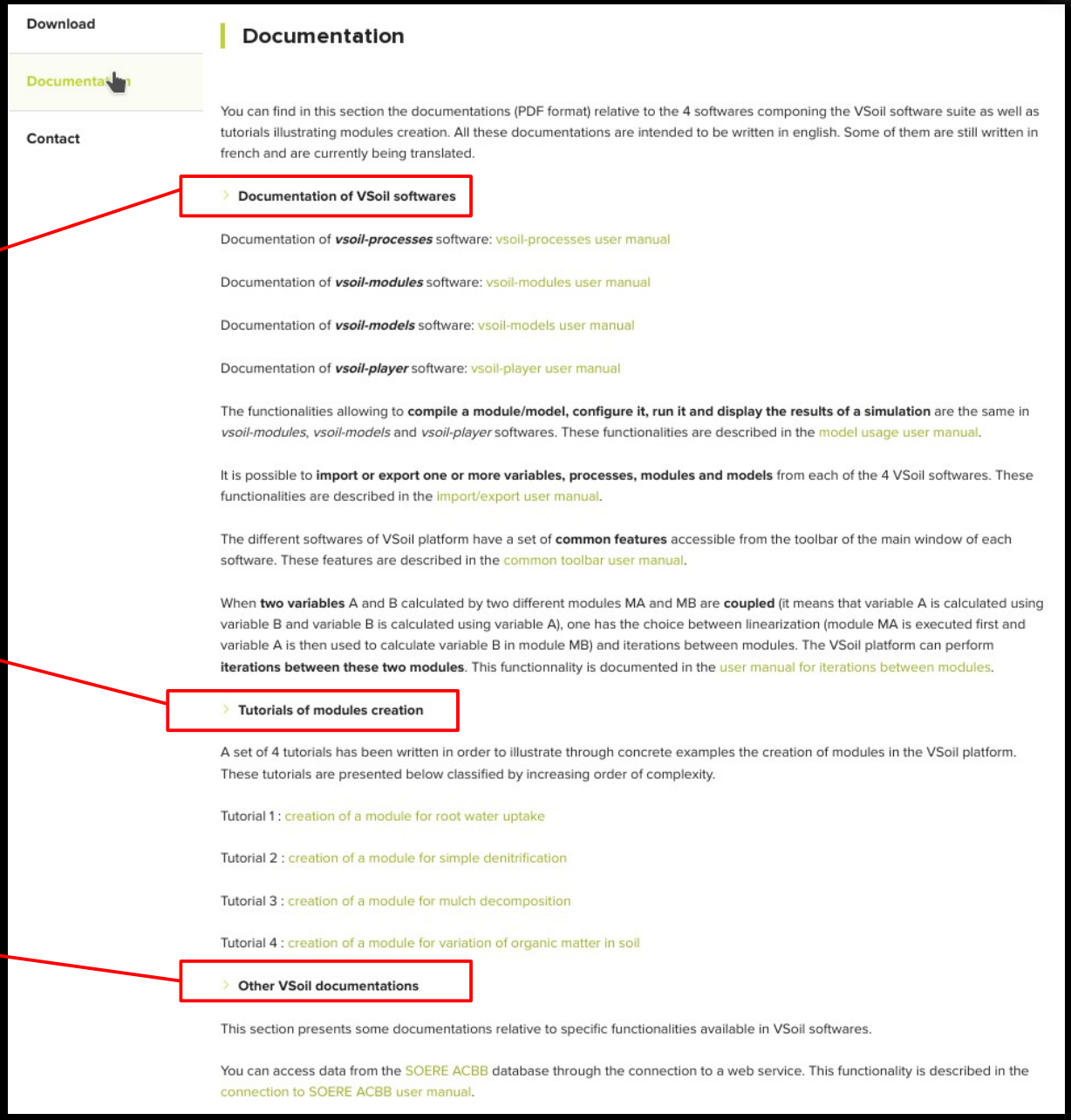
Resources

Website: https://www6.inrae.fr/vsoil/

documentations of the different softwares:
- vsoil-processes
- vsoil-modules
- vsoil-models
- vsoil-player

tutorials for creating modules

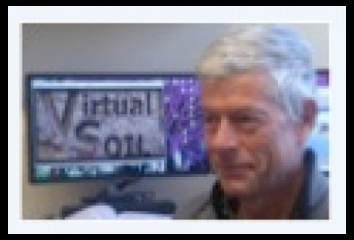
other documentations: connection to databases



The VSoil team

Team members:

- <u>scientific team</u>:



François Lafolie
(research fellow – scientific leader of the project)

Nicolas Beudez
(design engineer – scientific computing)

- <u>development team</u>:

Nicolas Moitrier
(research engineer – IT project manager)

Nathalie Moitrier
(design engineer – software engineering)

Cédric Nouguier
(design engineer – software engineering)

To contact us:

- vsoil@inrae.fr → scientific team
  vsoil-support@inrae.fr → development team

- Discord server

Thank you for your attention